

METAL

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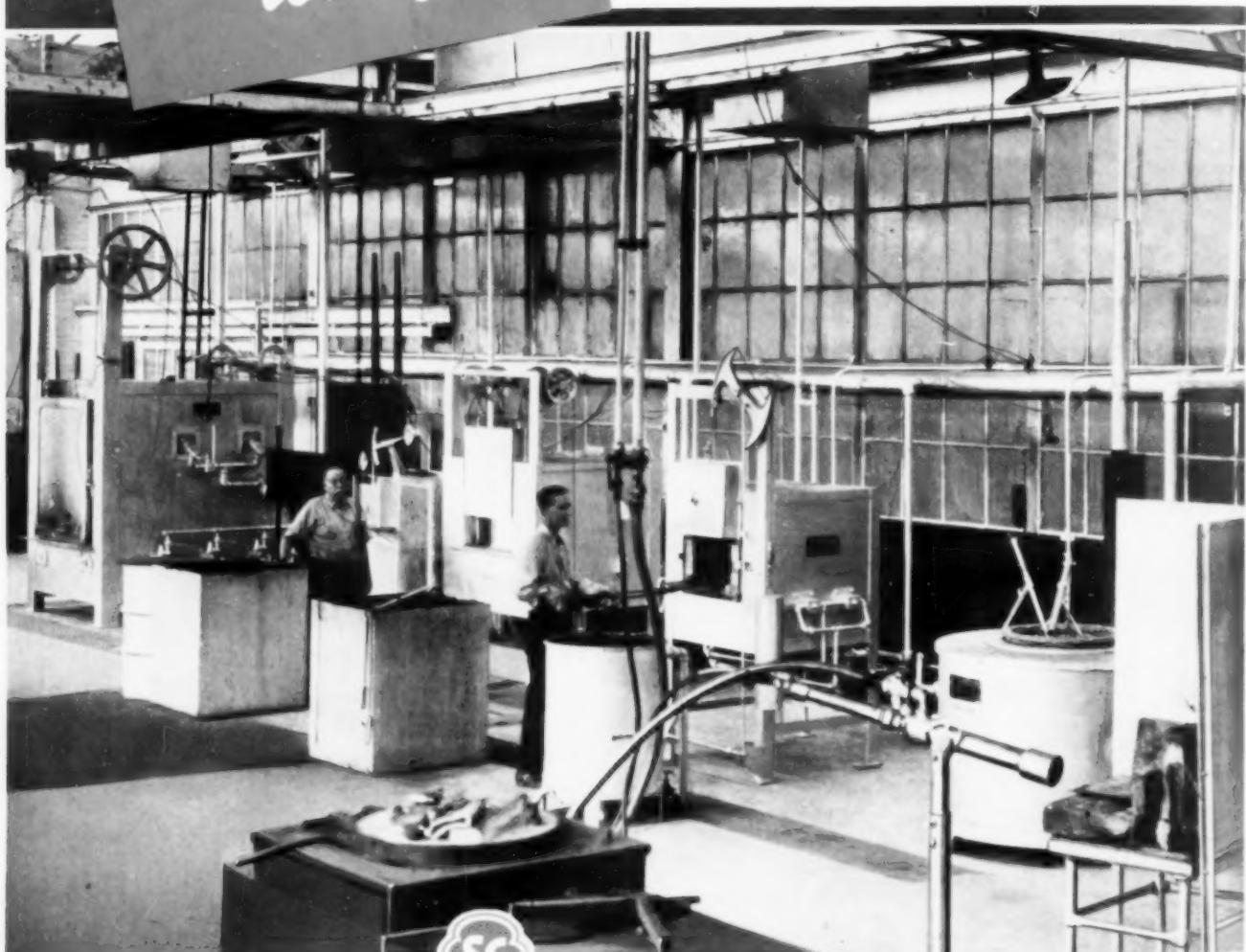
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M E T A L P R O G R E S S

Vol. 29

May, 1936

No. 5

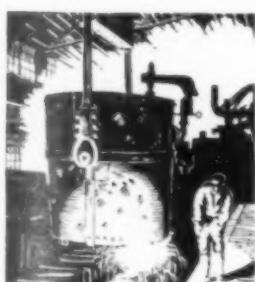
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Metal Progress: Page 2

An Editorial on Research

In 1926, Frank B. Jewett, president of Bell Telephone Laboratories, gave the commencement address at Purdue University and said, "Viewed from whatever angle you will, it seems to me clear that society as a whole has not only put the stamp of approval on research, but is showing every reasonable solicitude for its future . . ."

Since 1926 many things have occurred to upset this confident prediction. The depression has visited us. As to its cause or cure, your guess is as good as any economist's. The bitter fact is that unemployment has swept through the land like a plague, and is getting no better. Whether we like it or not, or whether there is in it any basis of fact or not, conviction is widespread that industrial research, time study and labor-saving equipment are largely responsible. Although Mr. Scott and his Technocracy have followed the chain letter into oblivion, more or less complete, a strong undercurrent of resentment still flows so strongly that President Roosevelt recently was moved to declare in effect that the cure for technological unemployment will be found not in less technology but by more intelligent allocation of the necessary labor.

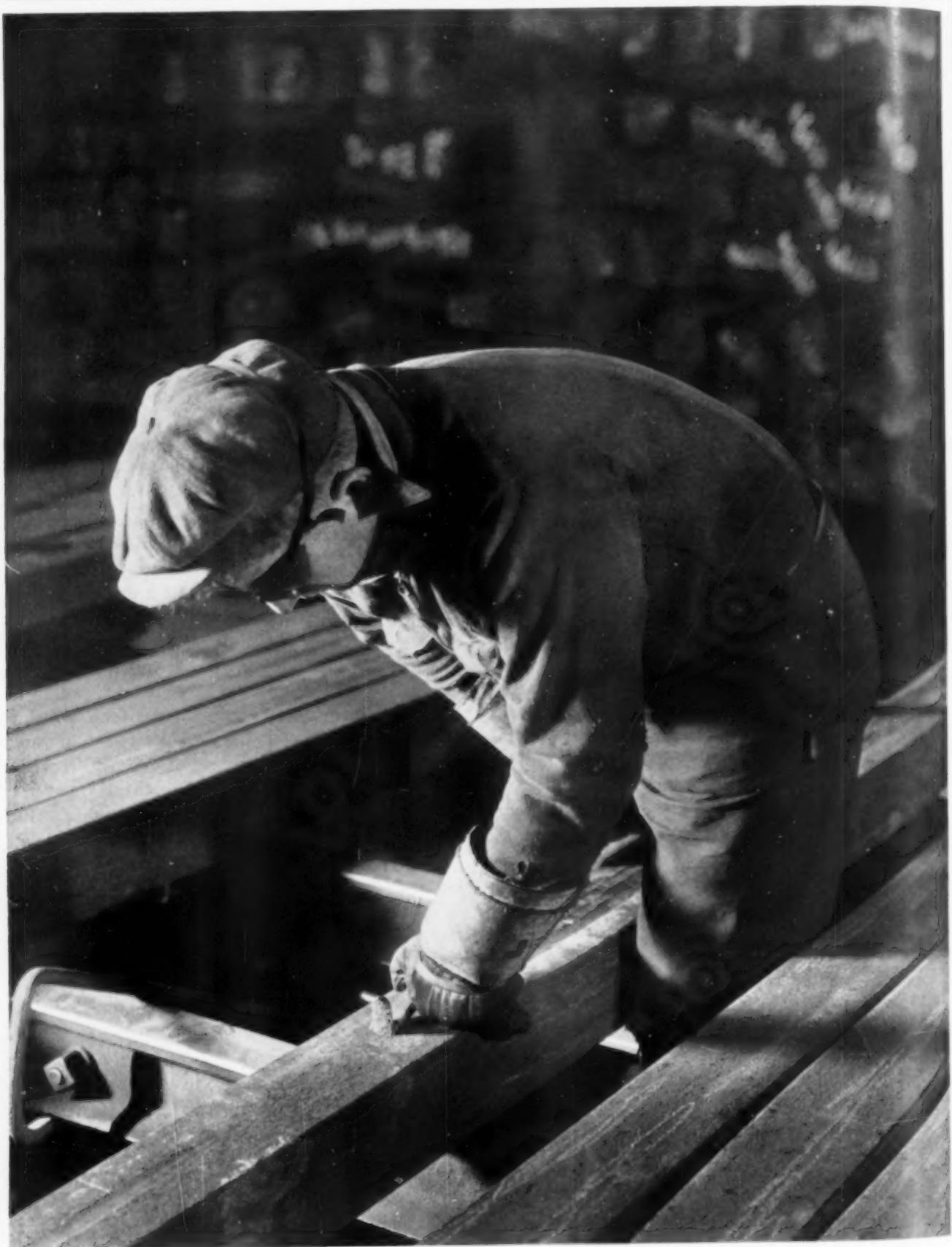
Even if for no other purpose than self preservation and to establish the facts, a new branch of research must be instituted. Projected inventions and "improvements" must be studied from a new angle — that of the public interest. This aspect of industrial development has so far been considered all to superficially.

Of course, the veritable scientific researcher, like Einstein, is free from such inhibitions but industrial research is more earth-bound. Probably some important industrial developments have been retarded or even placed in cold storage by their discoverers. Thus, Dame Rumor whispers that automatic gear shifters or gearless transmissions have been ready in automotive laboratories for a long time, and that television is ready but held back because it would render obsolete too much broadcasting equipment. But the point is that such delay, if any, has been based on the outlook for profit and loss in a single corporation or closely knit industry, and not upon the general well-being.

"People and materials are the things we can experiment with," remarked F. O. Clements, technical director of General Motors Research Laboratories. So far research has largely concerned itself with materials. Now it must enlarge its field to include people. Difficult though it must be, the problem of the industrialist and research chief is not ended when they have determined that a commercialized product will cut the manufacturing cost 5% or that it will not react unfavorably on other lines of output but result in a measurable gain in the net profit. They must go on and find out what it means to the customers, to the general public.

This thought is not a new one. The wider philosophical and humanitarian view was doubtless in mind when Robert Sosman said the following, when speaking on such a prosaic subject as silica brick before such a realistic group as the Iron & Steel Institute: "What does need to be looked out for, in an age of competitive nationalities, is that the nation which has the advantage of early access to new information, produced within its own borders and in its own language, does not forge too far ahead of the nation which depends principally upon its natural resources and its experience." And this was in 1929, blessed pre-depression year!

Dr. Sosman's view might have been inherited from his long stay at the Geophysical Institute in Washington, that organization devoted to the study of such unpractical things as earthquakes, mountain pressures, tidal forces, and volcanoes. However, Frederick M. Becket, president of Union Carbide & Carbon Research Laboratories, a man who has spent a lifetime in the study and development of alloys, showed that an eminently practical career leads to much the same conclusion. In a talk at a meeting commemorating Hall's discovery of aluminum reduction, he noted that the tempo of metallurgical research appears to have slowed down, due to the need for intensive study of minor areas whereas in earlier days a broad and quick survey of a new field was almost sure to discover some important item. The trend of the future, he declared, would be to study the effect of new discoveries on human relations, society generally.



Hammer, Hammer, Hammer, the Long Day Through

Alloy steel billets require much labor to remove surface imperfections, despite utmost care in ingot pits and bloom-mill. Carbon steel billets for seamless tubes also must have excellent surface; defects may be removed by flame

Cleaning Billet Surfaces With Oxy-Acetylene Flame

"IT CAN'T BE DONE" was the verdict ten years ago. The jury was a group of experts in the oxy-acetylene industry, weighing suggestions for the promotion of their business. The proposal was to chip surface defects out of steel billets, not with a cold chisel and air hammer, but with a cutting flame.

"It can't be done, because the cutting blowpipe is a tool for cutting *through* a piece of steel, not for shaving off the surface! In addition to this, most of this billet chipping is on alloy steel and the cutting flame hardens and sometimes cracks an alloy steel unless it is thoroughly pre-heated." So nothing came of the suggestion at that time. However, a near-revolution was then occurring in that branch of the steel industry that was manufacturing and selling pipe, and the next move was made by men in the mills who didn't know it could not be done!

The situation in the pipe industry was this: Seamless tubes had been perfected to the place where they were competing with lap welded pipe in large diameters, and for such seamless tubes there was an increasing demand for mild and medium carbon steel billets of excellent surface characteristics. Hot rolled billets which ordinarily would be rolled forthwith into skelp had to be cooled and surface defects removed.

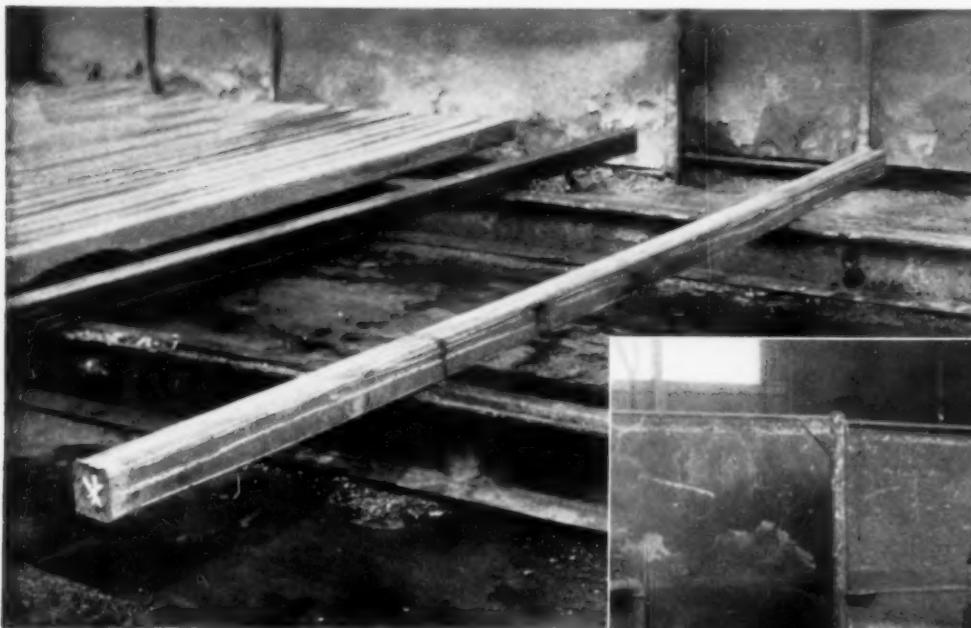
By Ernest E. Thum
Editor, Metal Progress
Cleveland

Consequently such a large tonnage of steel was going through the chipping departments that something had to be done to remove this "bottleneck" in production.

For instance, at the Ellwood City plant of National Tube Co. the capacity of available craneways and equipment was reached with 160 laborers leaning on chipping hammers. Even this crew was only able to clean the surface of one-quarter of the necessary tonnage; the balance was chipped at the point of supply, at a cost of about \$2 per ton. (It should be mentioned that the Ellwood City plant has no steel making department or blooming mill.)

Faced with this problem in plant economy, officials of the National Tube Co. insisted that the possibilities of the oxy-acetylene flame be at least investigated, as well as mechanical de-seaming equipment, such as massive planers or milling machines. In conjunction with Linde Air Products Co. and its associated equipment companies, a series of experimental developments in flame scalping lasting 18 months finally brought complete success.

It was found that eight special blowpipes could clean the surface of as much as 1700 tons of steel per day (this maximum figure, of course, depending on the condition of the billets), and all of it is cleaned in one small building. To determine comparative costs, a 75-ton heat was divided in three piles. One pile was cleaned by the old-fashioned chipping hammers, as shown in the view opposite. 500 lb. of metal was cut



At Top, Left, Is a Billet in Cleaning Yard With Inspector's Marks Showing Surface Defects to Be Removed. Below is operator with special cutting blowpipe removing these blemishes with the greatest of ease. On opposite page is photograph showing smooth, shallow gouges cut by the flame.



away; total chipping costs were about \$2.50 per ton of billets. The second pile of 25 tons was cleaned on a gouging machine (a special planer whose bed is forced past a large high speed tool by a hydraulic ram) with a loss of 1500 lb. of shavings and a cost of \$1.25 per ton. The last portion of the heat was cleaned with oxy-acetylene cutters; it lost 900 lb. in weight and the cost was \$1.00 per ton of billets.

A brief description of the successful method follows: First, the billets are pickled free of rust and mill scale. This is done in the open under the stockyard crane in two large tanks, 22 ft. long, 12 ft. wide, and 6 ft. deep, sunk below ground. These are of concrete, lined with paving brick set in melted sulphur mixed with clay for mortar — a construction especially durable against acid corrosion and the accidental battering received during loading and unloading. A tank load is about 200 tons of billets, the cycle of pickling and washing takes about two hours, and costs 15 to 20¢ per ton.

This lays bare the metal surface so that an inspector can readily mark any surface defects serious enough to be cut out. It also enables him to distinguish between major defects and those minor ones which will cause no trouble and disappear in subsequent rolling, piercing and drawing. Probably every inspector has his favorite word to describe typical defects, based on appearance, but the following is the terminology at the Ellwood plant, with suggested origins:

(a) Seams; long straight marks parallel with the corners, ranging in depth from very shallow guide marks (a minor defect) to $\frac{1}{8}$ -in. laps or cold shuts due to improper filling of roll passes. Sometimes a deep seam is due to a vertical crack through the surface of the ingot.

(b) Church steeple; sharp, Vee-shaped surface markings, pointed toward either end of the same billet. Cross cracks in the ingot roll out into this shape, due to the sides rolling out faster than the corners.

(c) Alligator hide; small wavy marks in various directions, $\frac{1}{16}$ in. deep or deeper, usually distributed over the entire surface. Origin is doubtful; perhaps due to skin blow holes in original ingot or to a tender skinned ingot. (Not a common defect in steel for seamless tubes, which is well deoxidized or killed before teeming into ingot molds.)

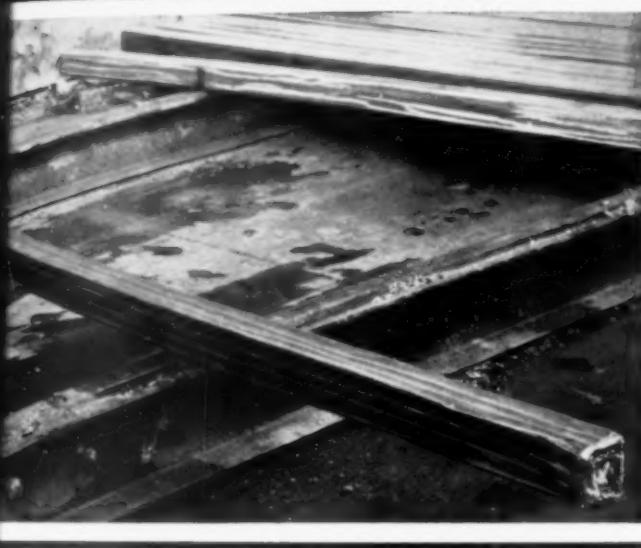
(d) Silica streaks; gross inclusions of dirt, slag, or refractory. Not very frequent, but ruin-

ous to any machine tool or cutter in a gouging machine, if such is used for scalping the billets.

(e) Scabs; a thin skin covering a shallow blowhole, not welded during rolling; usually from mold splashes during teeming.

(f) Black jack; a powdery substance held under thin surface scales or scabs. Origin probably the same as alligator hide.

Surface troubles vary considerably, heat to heat and mill to mill, and conditions are bettered as mills give more attention to the manufacture of steel suitable for seamless tubes. It is also true that probably twice as much metal is cut from a billet's surface as is really necessary, in order to catch major defects, masquerading as minor ones.



Scalping Operation

Billets (ordinarily 10 ft. long) from the pickling tanks are delivered along one side of a craneway, and laid side by side on a pair of railway rails, anchored 7 ft. apart, on the concrete floor. Here the inspector marks around or along each defect with soapstone; all four sides are marked in succession. Fairly high illumination is needed for this work, and is provided by overhead electric lights.

A second runway, exactly the same, is alongside, so the cutters can work on it while the other is being unloaded, loaded and inspected. Between these runways is a row of stations for the oxy-acetylene blowpipes, so that twelve cutters can work on either runway.

Just before starting the blowpipes, each operator takes a 4-lb. hammer and strikes the billet a

glancing blow at the head of each area marked by the inspector. This pushes up a small nib of metal above the general level, so that it will reach kindling temperature in the preheating flame much sooner than though a spot on a smooth surface were heated.

Now all is ready for work. The cutter, with a long-handled blowpipe (long enough so he cuts at knee level without bending over), heats the little nib to incandescence in 1½ to 2 sec., then tilts the cutting head so the gas stream is more nearly parallel to the surface and simultaneously switches on the excess oxygen. Immediately a white hot layer of burned iron spreads out over the surface of the billet, and the operator skillfully and rapidly follows this rushing stream of molten slag as far as necessary with the tip of the blowpipe. In 4 sec. a shallow channel 6 ft. long is cut in the cold steel. The cut is about 1½ in. wide, with tapering edges (an essential condition) and $\frac{1}{16}$ to $\frac{1}{8}$ in. deep depending on the angle at which the gas stream strikes the surface. Deeper cuts also are a little slower. The operator's skill consists in proper coordination of movements, to press triggers, tilt blowpipe head, and move it forward at proper speed; the hardest thing to learn is to start the cut without gouging a little hole in the surface.

The general effect is striking. The speed at which the flame moves forward, blowing out a stream of white hot, lava-like liquid ahead of it, is far greater than any operation with the familiar cutting blowpipes — spectacular though that may be. The consummate ease is also in high contrast with the back-breaking, ear-splitting conditions in an ordinary chipping shed.

Melted oxide that remains on the cold billet cools rapidly, and shells cleanly off without effort. The cut itself has only a thin coating of oxide, so thin it has the blue temper color of a watch spring.

The blowpipe now in use is shown in the photograph opposite, and is the result of a series of developments adapting standard cutting equipment to this specialized duty. As is well known, the latter projects a central jet of pure oxygen surrounded by four or six comparatively small oxy-acetylene flames. The tip of the blowpipe is usually of copper, whose high conductivity prevents the very end from getting too hot from radiated heat. Just behind the tip is a chambered head, with passages for mixing oxygen and acetylene and delivering them to the proper orifices. Three tubes lead from the mixing head back to the handle, where valves are located,

namely oxygen and acetylene for the preheating flame, and oxygen for the central cutting jet.

In hand operation the preheating flames usually burn continuously; when a spot of iron is heated to a full red, it will kindle and burn if a stream of pure oxygen strikes it. Thereafter the heat of the burning iron is sufficient to maintain the reaction and cutting continues; however, it is usual to keep the preheating flames burning, as they insure that the surface metal to be cut is well heated, and since they consume hardly $\frac{1}{5}$ or $\frac{1}{6}$ the oxygen required for the cutting jet. Obviously, also, it is necessary to control the oxygen in the cutting jet with a second trigger valve in the handle.

Type of Preheating Flames

Experimental development of this special blowpipe head involved the correct size and number of preheating flames so a small spot on a heavy mass of cold steel could be brought to red heat and the correct size of the central oxygen orifice to use the pure gas at the best efficiency. At present six holes 0.052 in. diameter are used for preheating, and a surprisingly large orifice ($\frac{5}{32}$ in.) delivers the oxygen. Gas pressures on the supply mains are 15 lb. per sq.in. for acetylene and 80 to 100 lb. per sq.in. for oxygen.

The tip itself is a drilled copper rod, about 6 in. long. A short steel sleeve is forced over the end to take the wear (the operator slides the blowpipe along the hot surface). The length of tip is sufficient to permit the operator to direct a glancing jet of oxygen along the surface—also enough so that heat conducted back into the mixing head will not cause premature combustion of the oxygen-acetylene mixture and cause a "backfire." Backfires are also caused by eroded or bell-shaped orifices; consequently all cleaning is done by a careful mechanic rather than by the operators jabbing away at the openings with a wire.

An interesting device, patented by the National Tube Co., enables the operator to light the preheating flames instantly and without effort. An insulated wire leads from an electrical condenser to the blowpipe head; a return wire leads from the grounded rails on which the billets rest. Just before the tip end of the blowpipe is lowered into contact with the billet, the operator grips the forward end of the handle with his right hand, opening trigger valves on preheating acetylene and oxygen lines. Immediately thereafter, an electric spark jumps across the closing gap between blowpipe and billet, and this ignites the

preheating flames. A second trigger is then depressed to start the cutting oxygen at the proper moment, and at the end of the cut the operator loosens his right hand grip and all valves close. His left hand, near the hose ends, steadies the whole implement.

The cutting equipment, with handle, valves, and hand shield, weighs in the neighborhood of 12 lb. This does not fatigue the operator unduly, as it hangs direct from one shoulder in a straight line. It also compares favorably with the 25 lb. of an ordinary pneumatic chipping hammer.

Oxygen and acetylene are delivered to the department in underground pipe lines. Each acetylene outlet has a hydraulic back pressure valve to guard against the chance that higher pressure oxygen may blow back through the acetylene hose of a defective blowpipe and enter the gas lines.

Acetylene is formed from calcium carbide in a battery of generators housed at a central point from which the gas is piped to all parts of the plant. About seven times as much oxygen as acetylene is consumed; special oxygen equipment was installed because the volume is rather too large for delivery in the standard 220-cu. ft. cylinders. This "dry-ox" system, so called, consists essentially of a pair of evaporators, operating alternately, for converting liquid oxygen into gas at the proper pressure for delivery through supply pipes. The liquid oxygen is carried from the oxygen producing plant to the evaporators in a tank truck.

Limitations of the Process

A few words may be said about the limitations of the process:

The shape of the billet has been a factor in its success. Ellwood plant is arranged to roll square billets into rounds for piercing. Other mills that start from a round billet would probably find that a machine like a lathe would be a more economical device. Likewise, the flame is not used on high carbon or alloy steel; the limit is about 0.30% carbon. Higher carbon billets should be warmed before scalping; otherwise alligator cracks will likely form on the bottoms of the cut troughs. At no time has it been observed that the cutting flame did any damage to the prepared surface of mild steel billets, except on one lot which was brought into the shed on a 30° below zero morning. Some were cracked by the heat before work was halted until the steel could be warmed.

Difficulties getting special attention of brass metallurgists are in deep drawing or forming presses, and corrosion in condenser tubes. Better metal for fabrication has come from improved mill practice on old alloys and improved corrosion resistance from new alloys

Copper Alloys to Meet Severe Requirements

THE USE of the term "severe requirements" does not necessarily indicate an unusual or spectacular application, although such are frequently met with. Many more instances of severe requirements are found in the ordinary, everyday uses of metals and alloys. Furthermore, the requirements for many such ordinary uses are being made increasingly more rigid, which in a large measure is due to economic necessity. Two main causes are contributing to this trend; first, there have been a large number of new alloys developed in recent years, obviously resulting in greater competition as between alloys; and second, depression years have made it necessary for users to economize in the purchase and use of materials more than heretofore. In one way or another they are therefore demanding and now getting materials to meet more severe conditions than in earlier years.

In general, the more rigid requirements may either result from (a) the type and severity of various fabricating operations or (b) from the character of the service to which the materials are ultimately subjected. In order to limit this discussion, one typical field where *fabrication* problems are predominant and another where *service* requirements are predominant will be de-

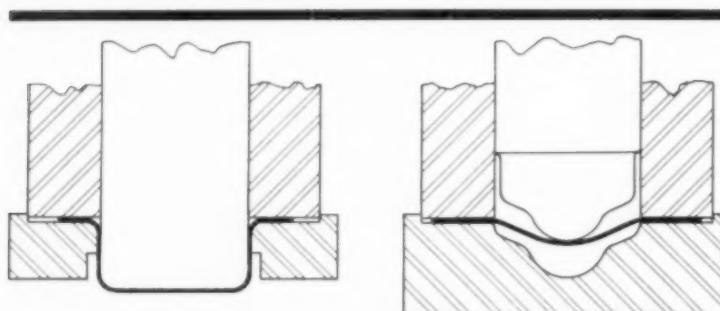
scribed as illustrative of the general trend in most fields of consumption.

The first class of severe requirements arises from the very common fabrication by the drawing and forming of sheet and strip. One major cause for increased severity of requirements is the demand for deep drawing stock which at the same time must have a very smooth surface in order to reduce or eliminate finishing costs. Inasmuch as a smooth surface depends on a fine grain size and deep drawing on a relatively larger grain size, these two factors are mutually exclusive and a compromise must be made. This compromise is no new development but the present tendency is to narrow the tolerance so much that a *very* precise control of temper and grain size is needed. This in turn means more expensive annealing, increased supervision, a greater amount of testing, and other extras. This effect of grain size is of somewhat less importance in ordinary "drawing" where the metal is ironed between a die and punch. It becomes of paramount importance where the metal is "formed"; that is, where the metal is stretched to an irregular contour and is not brought to final shape and pinched between die and punch until the very end of the operation. These two types of operation are shown diagrammatically in the first diagram.

A second cause of difficulty in drawing and forming shops is the tendency toward the use of thinner and thinner gages. For example, a given article formerly might have been made from stock 0.020 in. thick but the manufacturer

By D. K. Crampton
Research Director
Chase Brass & Copper Co.
Waterbury Conn.

now, in order to cut costs, wants to make it from 0.018-in. or even 0.016-in. material. The difficulty here is that the thinner the material the less the depth to which it can be drawn, so that an even more precise control of all factors in the brass



While Grain Size Is of Considerable Importance When Drawing Brass Between a Punch and Die, as at Left, It Is Paramount in Forming Operations (Right) Where Sheet Isn't Pinched Between Dies Until the End of Stroke

mill will be needed for satisfactory performance when the metal reaches the customer. The adjoining curves indicate why this difficulty arises. These show the result of tests on a series of different thicknesses of brass of 68% copper content. Test samples were annealed at various temperatures to produce varying grain sizes and tensile properties. The strengths and elongations for each gage are plotted as functions of the grain size, and the curves illustrate clearly the reason why decreasing the gage of strip increases the difficulties of drawing. Note particularly that for each gage of sheet the elongation falls off markedly above a certain grain size.

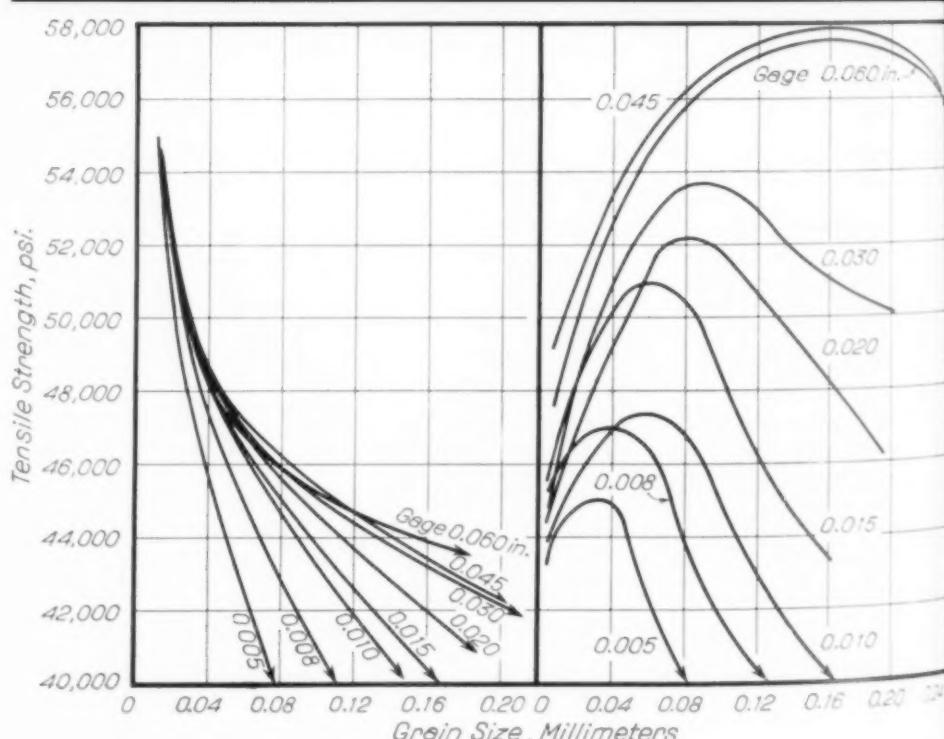
A third cause contributing to more rigid requirements for deep drawing stock is the tendency toward more complicated and difficult designs. There is a trend toward the elimination of separate parts requiring assembly, or toward substitution of a relatively light weight formed part for a heavier cast or forged part. In the decorative field the

modernistic designs are usually more angular, which in general means greater difficulty in fabrication. In the photograph there is shown a good example of a difficult series of operations of this general type — four steps in the fabrication of a modernistic design of side-wall light fixture. The first step is a very difficult forming operation. The re-forming operations with the numerous sharp angles in various planes introduce difficulties requiring very precise metal control in the mill as well as accurate tool adjustment by the fabricator.

A fourth cause results from the trend toward elimination of intermediate drawing and forming operations and therefore of intermediate anneals. This of course only applies to articles so deep or so complicated that normally several separate operations with suitable intermediate anneals are used.

A fifth factor contributing to more severe requirements is met when an article requires a deep drawing capacity together with the ability to be machined readily — again a pair of mutually contradictory properties.

The challenge of the tendencies just described is ordinarily met, not with any radical

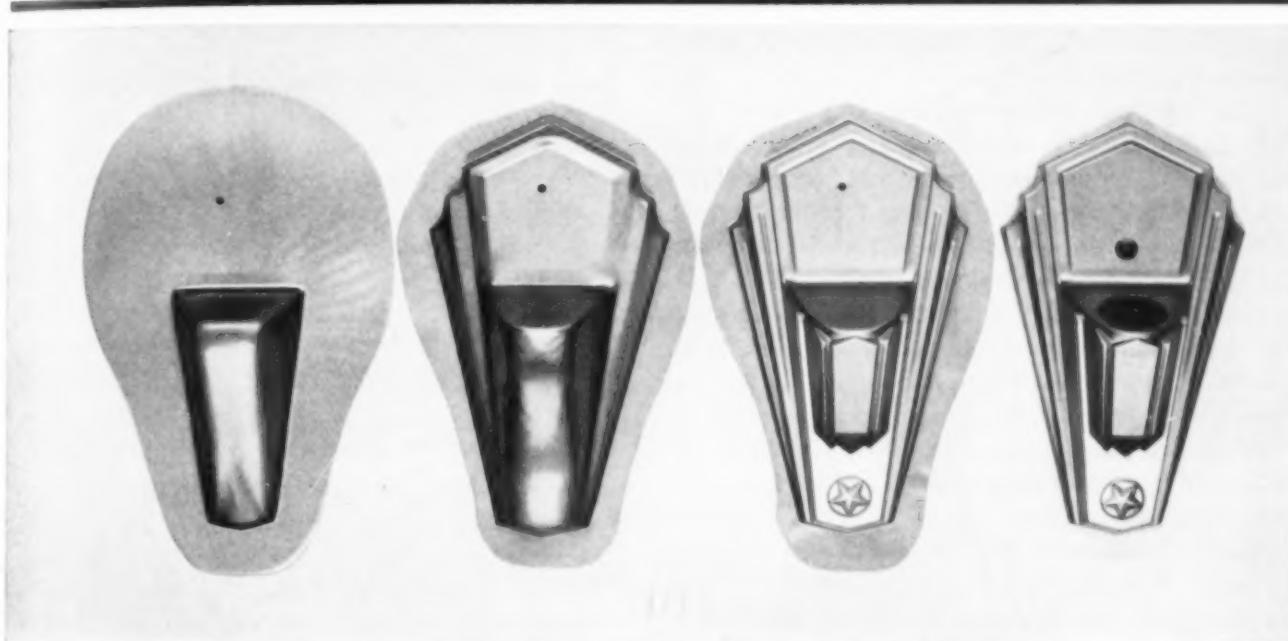


Tensile Strength of Eyelet Brass (68% Cu, 32% Zn) Steadily Lowers With Increasing Grain Size, but Each Gage Has a Well-Defined Maximum of Ductility at a Characteristic Gr

change of alloy or treatment, but rather by a more precise control of quality of the commonly used alloys. In general the use of eyelet brass of 68% copper, 32% zinc, very low in lead and iron, is found well suited to the most difficult operations. This alloy shows about the highest combination of strength and ductility of any of the brasses; as far as ability to undergo a single cold working operation of any type is concerned, there is no advantage in a higher copper content. And it might well be pointed out that

Third, when a fabricated article is to be brazed with so-called spelter solder (about 50% copper, 50% zinc), it is necessary to fabricate it of an alloy of 72% copper or preferably even 75% copper in order that it have a melting point sufficiently higher than that of the solder.

Regardless of the copper content of the brass selected, it is necessary to pay increasingly careful attention to impurities as the severity of the fabricating operations is increased and as the gage of the metal is decreased. The two impuri-



Deep Draws and Sharp Angles on Modernistic Designs Require Precise Metal Control in Brass Mill and Accurate Tool Adjustment in the Fabricating Shop

only for *very* severe drawing or forming jobs is this alloy found better than the common high brasses of 65 or 66% copper.

There are, however, three factors which, when present singly or in combination, favor the use of an alloy with higher copper content:

First, where the type of operation is such as to introduce susceptibility to season cracking and a relief anneal is not desired, a copper content of over about 80% is indicated. Incidentally, the type of cold working operation is tremendously important in determining the tendency to season crack—more than is generally realized.

Second, where repeated operations without intermediate anneals are desired, it is found that the alloys containing from 85 to 95% copper can be worked much more without failure than the lower copper content alloys.

ties invariably present are lead and iron. On severe forming, lead tends to cause cracked edges. Iron, even in small amounts, appreciably hardens all copper alloys. High grade drawing brasses are therefore kept to lead and iron contents each of 0.05% max.

For drawn articles requiring subsequent machining a compromise must frequently be made between best workability and best machinability. For such uses brasses with lead contents as high as about 1% are frequently used. In general, higher lead can be tolerated in heavy walled articles than in thinner walled ones. With suitable design and adjustment of tools surprisingly difficult articles can be drawn or formed from such machinable brasses.

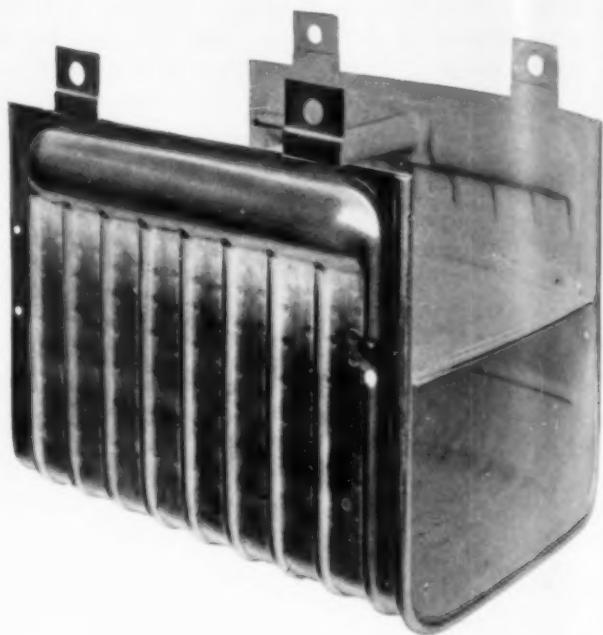
The accurate control of "temper" becomes increasingly important as the severity of the

drawing operation increases. Annealed temper is commonly defined by the trade in terms of grain size. Formerly a considerable variation in grain size was quite common, due to lack of suitably controlled annealing furnaces in the mills. Modern furnaces, however, are capable of much more accurate control. For most work under present conditions, the permissible range calls for an upper limit of about twice the lower limit; for instance, a range of 0.015 mm. to 0.030 mm. grain size, or perhaps 0.025 mm. to 0.050 mm. grain size would be supplied. Where necessary, it is possible to keep within a range where the upper limit is not more than one and one half times the lower, as for instance grain size 0.030 mm. to 0.045 mm.

Surface texture and condition of the material becomes increasingly significant as the operations performed become more drastic and complicated. It is found that complete freedom from all traces of dirt, thin oxide films, and traces of acid from pickling must be eliminated. The surface texture as controlled by the condition of the rolls and the degree of anneal and care in pickling is also very important. Finally, a good lubricant uniformly applied and a nice adjustment of forming tools frequently determine the success or failure of a given operation. Many types of lubricants can be used but none appears better and more economical than a heavy soap solution made from a good grade of chip soap.

In fabrication not only are the ability of the metal to be worked and a low cost of finishing essential to success, but frequently many other factors appear. Take for example a refrigerator evaporator such as shown. This is an excellent example of very severe metal requirements. The evaporator is made from two sheets, blanked and formed in a heavy press to make the large bulge for the boiler and the channels for conducting the refrigerant. This is a severe forming operation and requires material of high strength and high ductility, together with a nice adjustment of tools. It is perhaps hardly necessary to mention that absolute freedom from physical defects is necessary to prevent breakage.

The completed unit is tested for freedom from leaks. Finally, the evaporators are again cleaned and tin plated. Here a smooth surface is essential to good appearance, necessitating a reasonably fine and well controlled grain size in the original sheet. Inasmuch as there is a considerable weight of metal involved, it is essential to get the cost as low as is feasible, consistent with good performance, so the thickness of the metal is held to a



Evaporator Unit of Silicon Bronze Sheet, Combining High Strength, Good Workability and Weldability, and Smooth Surface.

minimum, which means that only a high strength alloy capable of withstanding high pressures can be used.

These are certainly difficult requirements. To meet them requires material with a rather unusual combination of properties. One type of copper alloy, silicon bronze, appears to be the only type which meets them all, and there are several of these silicon bronzes on the market. All contain about 3% silicon and may contain lesser amounts of any of several such elements as zinc, manganese, aluminum, tin or iron. This particular evaporator is made from an alloy of Cu 96%, Si 3%, Zn 1%.

Corrosion Resistance

So much for the severe requirements due to fabrication. A second field is where service requirements are severe and require quite different alloys from those described above. Typical of this are the condenser tubes for central station, marine and oil refinery service.

This field is so complex that no attempt will be made to cover it in any detail. It is simply pointed out that with the modern trend toward high steam pressures and higher operating economies, the corrosive conditions to which all such tubes are subjected are intensified. In

many plants an increase of the amount of condensate per unit of tube area has resulted either in higher average operating temperatures or higher water velocities inside the tubes. Either factor tends to increase the rate of corrosive attack. In addition, harbor waters (where many central stations are located and where ships dock) are increasingly contaminated from industrial wastes so that the cooling waters are increasing in intrinsic corrosiveness. In the oil field new processes are being developed constantly, many of them at higher operating temperatures. Unfortunately most oil refineries are located where nothing but highly corrosive waters is available, and many of these get worse as time goes on.

Although numerous types of failure of condenser tubes have been described in the literature, there are three which have been much more prevalent than others and which together account for a very large proportion of all failures of non-ferrous tubes. These are dezincification,

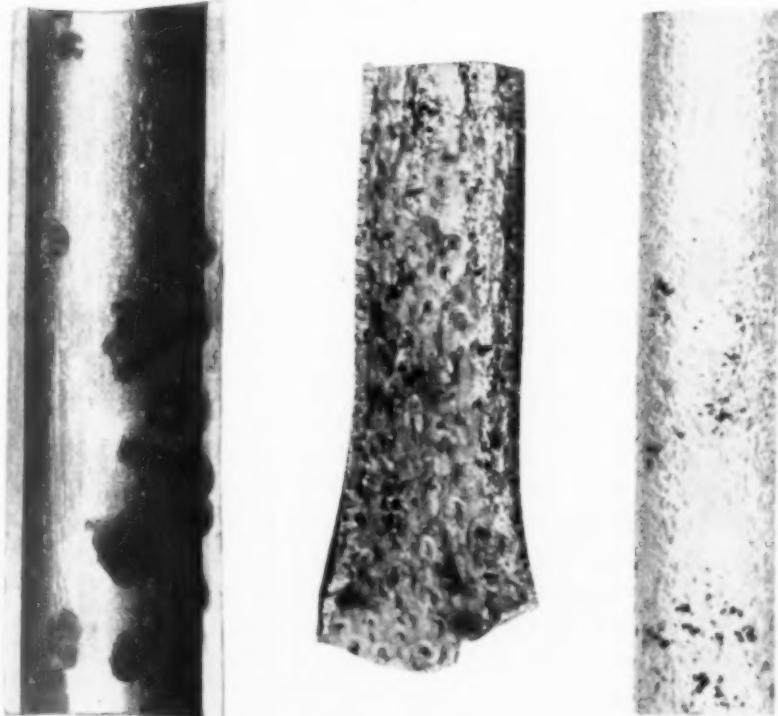
impingement attack, and pitting. The admiralty alloy, formerly largely used for these tubes, was susceptible to each under certain conditions.

The left photograph of the group on this page shows a section through typical dezincified plugs in an admiralty tube. The corroded zones are very spongy and porous, resulting in a steady seepage of water when the attack progresses through the wall. Where admiralty has been found not quite good enough, and where the failure has been due to dezincification, the most logical replacement material is red brass. The latter alloy is immune to dezincification and, under conditions which dezincify brasses of high zinc content, gives economical and very satisfactory service.

The central view shows the appearance of a tube which has failed by impingement attack. The small, horseshoe-shaped, pitted areas are typical of this type of attack, which is very serious in marine condensers where high circulating velocities are quite common. A few years ago an alloy known as aluminum brass and containing 76% copper, 22% zinc and 2% aluminum was developed specifically to overcome this attack. Due to the aluminum content a very tenacious surface film is rapidly formed which resists rupture by impingement of the air bubbles and very effectively prevents attack of the tube. The alloy in actual service has given many times the life of the tubes it has replaced.

While aluminum brass is excellent for resisting impingement attack where the water temperature is low or moderate, it has been found very susceptible to dezincification as temperatures are increased. Therefore under conditions where both impingement attack and dezincification can occur, a still different alloy is necessary. One recently developed which has been found to meet the requirements is an improved aluminum brass containing about 82% copper, 15% zinc, 2% aluminum, 1% tin. This alloy is fully as resistant

(Continued on page 100)



Dezincification

Impingement Attack

Honeycomb Pitting

Three Types of Corrosion of Condenser Tubes That Have
Been Successfully Met by the Formulation of New Alloys

Large coiled springs and all leaf springs are formed from hot bar stock. Subsequent heat treatment has a notable effect on their static properties and endurance. Some tests are also described showing the dangers of corrosion either prior to installation or during service

Hot Formed Mechanical Springs Manufacture and Life

HOT FORMED SPRINGS are commonly of two classes, the helical or coiled spring and the elliptical or leaf spring. Essentially, the mechanical hot forming of these two general shapes is a somewhat simple procedure. The apparent simplicity of production becomes more involved when, in the face of competitive costs and quantity production, power driven, high speed coiling machinery is substituted for manual equipment. Mechanical difficulties also increase greatly when the manufacturing field is extended into miscellaneous production, which may frequently include bar diameters of $2\frac{1}{2}$ in., bar lengths of 600 in., and individual coil springs weighing up to 300 lb. But full appreciation of the highly specialized nature of spring manufacture does not result until it is realized that service conditions and specifications are such that it is common practice today to produce springs which must operate successfully at stresses up to 150,000 psi.—such demands make the mechanical spring one of the highest stressed parts used in modern mechanisms.

As a result, the originally simple manufacturing equipment and methods are no longer adequate and production becomes more involved and complex. Furnaces of questionable design and

control, low speed manual coiling machines and insufficient testing apparatus and methods must be discarded and replaced by suitable furnaces of positive and close control, high speed automatic coiling equipment and one other form of equipment which is of primary importance today. Reference here is made to the physical and metallurgical research laboratory. Present service demands are such that the physical testing field has extended beyond the simple equipment required for hardness determinations and load deflection measurements. While these two tests are still essential, they are no longer adequate in themselves and the manufacturer whose testing equipment is limited is seriously handicapped during any investigation of the problems arising during production and use.

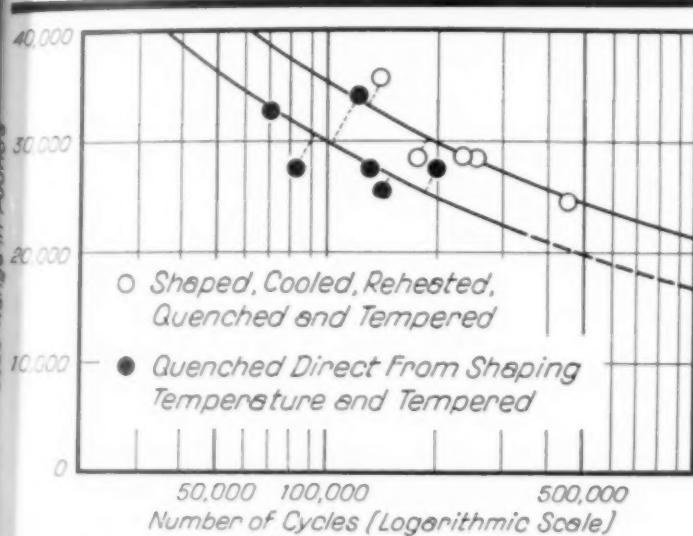
Testing equipment is needed that will disclose the physical properties of the bar and flat stock as well as of the finished spring. Testing machinery is necessary for the close determination of elastic properties, maximum loads and breaking strengths, ductility, hot and cold bend resistance, hardness, and impact resistance of bar and flat stock. In addition, other testing equipment must be available for the physical testing of finished springs for the determination of fatigue resistance under repeated torsional and bending loads, for their hardness and load-deflection characteristics.

The incoming steel stock, as received from the mill, should also be checked for chemical analysis, segregation, seams, size variations,

By Armand H. Peycke
and Robert W. Clyne
Vice President and Sales Engineer
American Steel Foundries, Chicago

hardenability, and depth of decarburization. The metallurgical research division must deal with such problems of spring steel as grain size effect, normality vs. abnormality, carbide segregation, scaling, decarburization, quenching rate and properties of quenching media, factors affecting hardness penetration and uniformity, corrosion, microstructure, production heat treatment and the influence of time-temperature effects during heat treatment.

All forms of elliptic shapes are made by hot forming. Hot formed mechanical springs usually include all coil springs made of $\frac{3}{8}$ in. diameter bars and larger. The method of forming in the smaller size bars is more or less a function of the ratio of mean coil diameter to bar diameter.



Fatigue Tests on Carbon Steel Elliptic Springs (Multi-Plates of $4\frac{1}{2} \times 7/16$ In. Section) Show That Double Heat Treatment Is Better Than Quenching Direct From Shaping

Where initial tension is required in the spring, cold coiling is requisite. The American Steel Foundries is a producer of all types of hot formed spring shapes of carbon and alloy steels. The spring works is located at Hammond, Indiana, and has a capacity of 1500 tons per month of railroad and industrial springs. Thirty years of experience in the field of heavy spring production and application has resulted in methods of physical design and stress analysis that have proved of great value in the solution of critical railroad and industrial problems. Accompanying the advances in mathematical analysis have been continuous researches in metallurgy, fatigue of metals and other aspects of physical testing which are reflected in the design and use of high

speed flexible shaping equipment, automatic heat treating equipment, and a fuller and more comprehensive understanding of the factors that affect spring life.

Heat Treatment of Heavy Springs

The sequence of heating operations practiced by us in the manufacture of heavy springs (or long or sharply coiled springs) is based upon the fact that the microstructure after hot forming is coarse and undesirable and therefore a subsequent heat treatment for grain refinement is necessary. Our metallurgical researches on inherently fine or coarse grained steels indicate, however, that this practice (the so-called "double heat treatment") may be modified in the future. At present, and with the majority of spring steels now available, practices which definitely separate the heating for forming from the heating for grain refinement are decidedly superior to practices which allow for shaping and quenching from the same heat.

Forming temperatures are necessarily high, in order to coil or otherwise shape heavy springs with speed, ease and precision. If the steel is removed from the heating furnace at the temperature most desirable for grain refinement, the time required for shaping will allow such heat losses at plate edges and bar ends that excessive pearlite will form and upon quenching will be retained in the microstructure. This condition is most undesirable.

On the other hand, if steel (not of controlled grain size characteristics) is raised to a temperature sufficiently high to compensate for the heat losses above mentioned, excess grain growth is promoted and is retained upon quenching from the shaping operation, despite the fact that the temperature of the steel at the moment of quenching may be only slightly above the critical temperature, A_{rs} . The resultant microstructure is coarse and is unfit for severe service. The high temperatures involved also form an excessive amount of scale (frequently in the form of blisters) and general surface roughness. Thick iron oxides loosely adhering to the surface seriously retard quenching speed and hardness penetration; scale may also be worked into the surface of the steel during coiling, thus instigating minute surface notches which may lead to early fatigue failure of the spring in service.

In general, the quenching of heavy springs direct from the shaping operation is a practice that should be avoided, for it is not conducive to

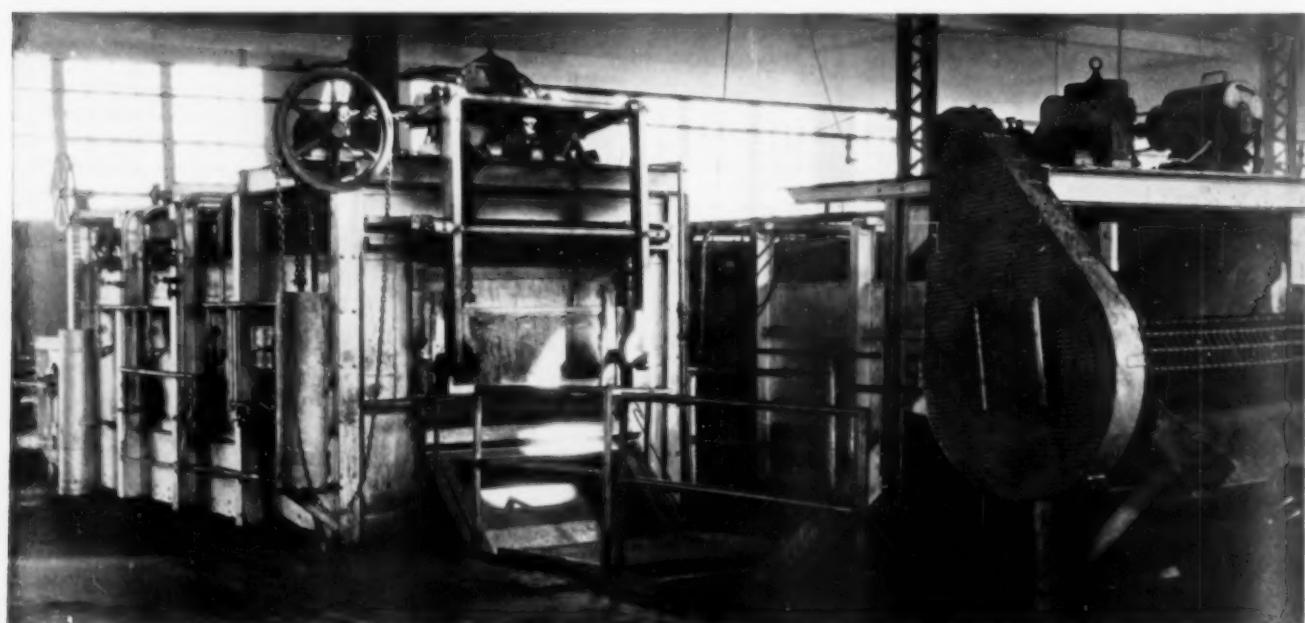
uniformity of structure or high resistance to dynamic stresses. Proof of this is contained in the first curve, which compares the fatigue resistance of a series of multi-plate railroad springs of carbon steel, $4\frac{1}{2} \times \frac{7}{16}$ in. section, quenched direct from the shaping operation (solid symbols), to the resistance offered by a series of the same springs cooled in air from the shaping operation and then reheated for grain refinement and quench (open symbols). Quenching temperatures used in both types of heat treatment were common temperatures which have been regularly used in the production of railroad springs; both sets of springs were tempered in the same furnaces for the same length of time at heat and at the same temperature. (Unfortunately, the limiting frequency of the fatigue machines used for this test was 50 cycles per min. and hence it was not possible to extend the diagram as far to the right as is desirable, and determine the eventual endurance limit.) Examination of the plotted points shows that quenching from the shaping operation results in wide scatter of the test results and a material decrease in resistance to dynamic stresses. Neither is conducive to increased service life.

Furnaces subject to close temperature control are essential to continuous production with double heat treatment, and high speed shaping equipment and other production machinery are, of course, requisite to the objective of low costs.

Furnace design, as affecting flame, atmosphere and temperature control, is of primary importance, for if the double heat treatment is carried on in furnaces which promote heavy surface oxidation and pitting, the advantages of the treatment will be materially reduced.

Three photographs illustrate some of the furnaces installed by American Steel Foundries for this purpose. The first is a gas fired, continuous, chain belt conveyor type, reheating furnace designed for helical springs only. The limiting temperature range of this furnace is 1750°F. and firing is with 1000 B.t.u. mixed gas through 14 burners, eight overfired and six underfired, arranged in two zones each with motor operated valves. Temperature control is by means of recording pyrometers of the potentiometer type. Temperature of the steel in transit is held within narrow limits; one reflection of this close control is a high degree of uniformity in hardness following quenching. The conveyor inside the furnace is of the endless chain belt type, 3 ft. 6 in. wide, and is made of heat resisting alloy. The furnace discharges through a chute, which may be sealed, into an automatic quench tank, the oil in which is under forced circulation and subject to temperature control.

A furnace of the type used for heat treatment (or heating prior to shaping) of elliptical spring plates is shown in the second photograph. This oil fired furnace of the continuous chain



Large Helical Springs, Cooled After Hot Forming, Are Hardened in This Automatic Heat Treating Furnace, Quench Tank and Conveyor-Elevator

conveyor type is bound with steel plate and is 16 ft. long inside, 6 ft. wide, and 15 in. high to the skewback. Temperatures are pyrometrically controlled; the furnace is fired through five under-fired burners, arranged in two zones each with motor operated control. Flame and temperature control are such that decarburization and scaling are reduced to a minimum.

The principal furnace used for drawing of both elliptic and helical springs is shown next. It is of the continuous apron conveyor type with a capacity of 5600 lb. per hr., and has a temperature range of 500° F. to 1000° F. It is a three zone, gas fired furnace and the steel passing through the final heating zone is held to within ± 10 ° F. by potentiometer type recording controllers. The conveyor is 65 ft. long by 5 ft. wide. Study of time-temperature relationships during operation has resulted in a high degree of hardness uniformity, a reduction in the internal stresses and increased uniformity of their distribution, as well as a considerable increase in the apparent elastic range of the treated steel springs.

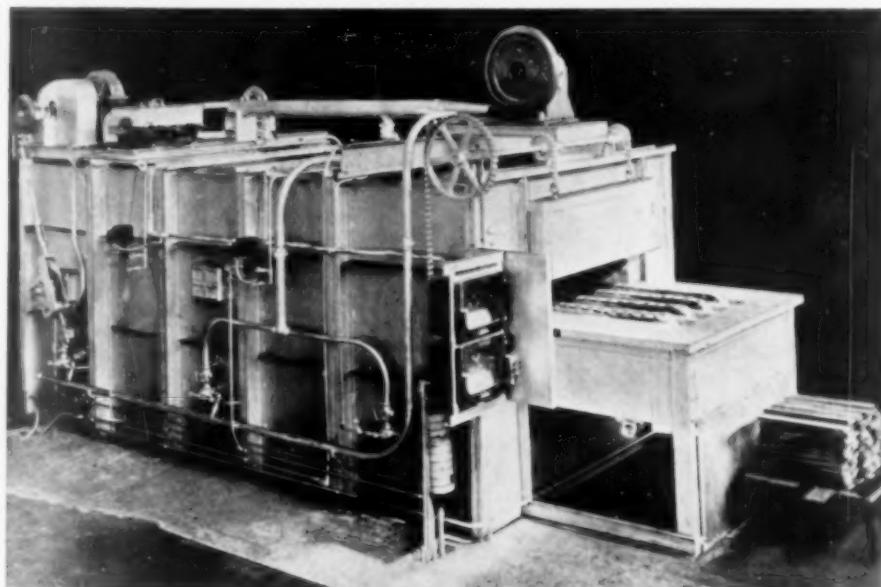
Problems of Manufacture and Use

While the majority of spring problems which deal with failures are encountered in service, nevertheless, two rather distinct classifications may be determined — namely, problems that are primarily of a manufacturing nature and problems that are primarily of a service nature. The

manufacturer must be concerned with researches on both classifications if the full confidence of the purchaser is to be secured. Researches on corrosion-fatigue, stress analysis, allowable width of fatigue range at varying mean stresses, and general spring design are examples of what might be termed "service research," for these problems are not specifically related to manufacturing procedure. The American Steel Foundries has been particularly active in this field and, in addition, has developed theoretical equations substantiated by laboratory tests which determine the effects of such pertinent spring problems as those of curvature, inactive end turns, initial set, banding stresses, leaf pressure and form of plate ends.

Appreciation of the fundamentals of a problem is essential to solution, and research is frequently a requisite to appreciation. Hence, initial research does not necessarily strike at the desired final objective — which of course is solution. Corrosion is probably the most serious unsolved *service* problem confronting manufacturers of springs, and the most serious *manufacturing* problem remaining generally unsolved is apparently that of decarburization. Undoubtedly one of the greatest obstacles to their practical solution is the lack of appreciation of their extremely adverse effects on the service life of many mechanical parts, including steel springs. It is very difficult to trace spring failures to either or both of these possible sources if neither is suspected, and this is generally the case in the absence of previous research.

There is need for commercial research in this country on both these subjects, principally so that widespread appreciation will result therefrom. Given this necessary general appreciation of the fundamental natures of these problems, individual researches will probably provide the answer to that persistent question, "Well, what can we do about it?" The great majority of railroad springs, tractor and other road machinery and industrial springs are exposed to the influences of corrosion and decarburization. Fortunately, however,



Oil Fired Furnace for Heating Spring Leaves Prior to Forming and Prior to Hardening. Flame conditions are adjusted so as to hold scale at a minimum

the length of service of the great majority of these springs is reasonably satisfactory.

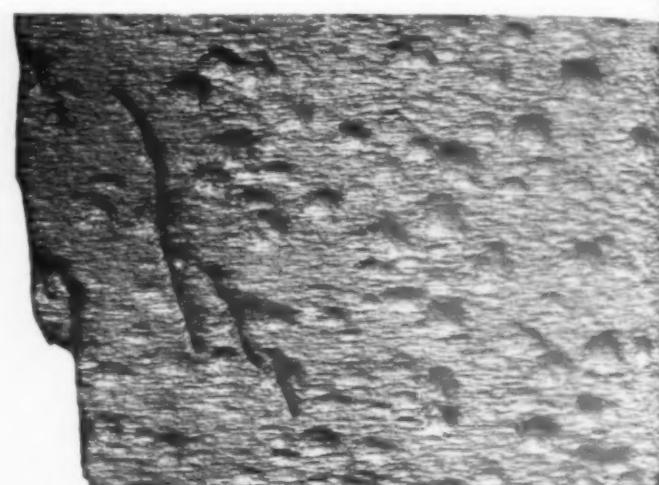
Nevertheless, we are much concerned with these springs for we are greatly interested in the possible weight ratios which might occur and be decidedly favorable in the absence of these two sources of failure. But at present we are principally interested in those springs which failed during service and in determining the cause and, of course, methods of preventing repetition of failure. It is not improbable that appreciation of corrosion and decarburization may clarify many of the failures which still occur apparently "without cause."

All hot formed railroad springs are exposed to the elements and therefore are subject to corrosion. It is easy to believe that, under some conditions of service, corrosion is the principal contributor to failure. D. J. McAdam, Jr., metallurgist at the United States Bureau of Standards in Washington, has made a sound and continued study of the fundamental behavior of metals under various conditions of corrosion and repeated stress. These researches have been conducted upon machined and polished specimens of ferrous and non-ferrous metals in a wide range of composition and properties, and detailed consideration was given to the influence of cycle frequency, stress range, water composition and oxygen concentration. High speed reciprocating machinery has directed considerable engineering attention to the influence of such obvious surface notches and discontinuities as grooves, oil holes, fillets and tool marks. Realization is not so common, however, in the general engineering profession, that the principal adverse effect of simultaneous dynamic stress and corrosion is the chemical formation of notches which are similar in effect on stress concentration (and ultimate failure) to mechanically formed notches. The question is emphatically not one of reduction of cross-section by corrosion. These facts and others have been established by experimental research on machined and polished specimens by Dr. McAdam, and have been published in a series of papers during the last ten years.

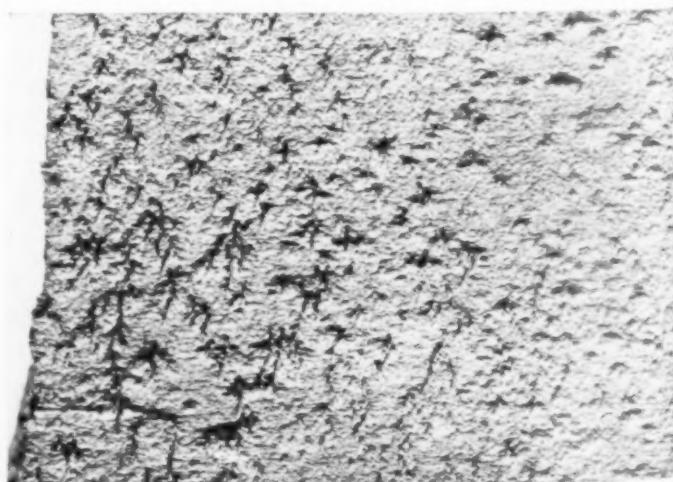
In steel springs, however, as contrasted with carefully prepared laboratory specimens, the issue is complicated by the presence of surface decarburization as shown by Hankins and Becker in *Journal of the British Iron and Steel Institute* in 1931, and, in the absence of research data, the possible corrosion effects have been controversial. Our preliminary researches upon the subject have shown that spring steels, tested full



Stress Corrosion on Tension Side of 1% Carbon Spring Steel Lug From Refrigerator Car After 12 Months' Service. Magnified three thousand times.



Pits in Spring Plate of Chrome-Vanadium Steel Formed in a Machine During Which Assembled Spring Was Periodically Dipped in Ammoniac Solution. Premature failure of corroded spring was tested dry shows effect of stress concentration at pits. Magnified three thousand times.



Carbon Spring Steel Tested as Above Develops a Multiplicity of Cracks Within 1.5 In. of the Parting Line. Magnified three thousand times.

size in the form of elliptic and helical springs and necessarily in the "as heat treated" surface condition, are adversely affected by both stress-corrosion and prior stressless-corrosion. By "stress-corrosion" is meant simultaneous dynamic stress and corrosion. "Prior stressless-corrosion" is intended to indicate a two stage test, the first stage of which is corrosion in the absence of stress and the second stage is fatigue in the absence of further corrosion in order to determine the reduction in fatigue limit due to the corrosion stage. The comparative basis is, of course, the fatigue limit of uncorroded specimens.

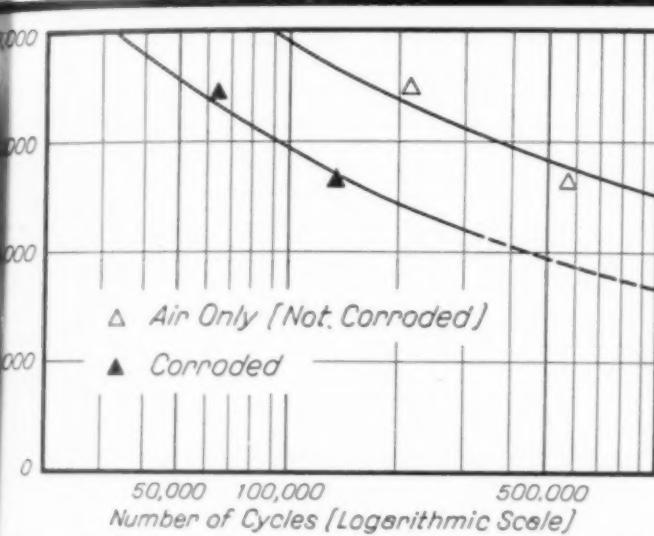
Some corrosion effects which are the results

steel elliptic plate. The full size banded spring had been subjected to thirty days intermittent dipping (no exterior load on spring) in a concentrated sal ammoniac solution. The spring was then allowed to drain and dry and was subjected to repeated loadings in air, whereupon premature failure occurred — indicating a corrosion effect. It should be noted that the corrosion pits are large, round and dish shaped. It is also interesting to observe that the photograph shows a corrosion crack clearly extending into the line of fracture.

Finally a plate of carbon spring steel is shown which had been subjected to laboratory stressless-corrosion and then fatigue in a similar manner to that just described for the chrome-vanadium specimen. Here, a multiplicity of corrosion cracks are apparent near the line of fracture, while few, if any, are evident at the right of the photograph, 1.5 in. away from the fracture. The cracks originated, of course, during the fatigue phase of the test.

Last is a graph showing the influence of prior stressless-corrosion (30 days intermittent dipping in concentrated sal ammoniac solution) on the fatigue resistance of chrome-vanadium railroad springs. Open symbols, termed in the legend "air only," are for specimens tested in the absence of corrosion; solid symbols, termed in the legend "corroded," refer to specimens subjected to prior stressless-corrosion. While only four points are plotted, the slope of the curves was taken from the slope of a curve established by tests in air of seven carbon steel springs which were operated through seven different stress-ranges from a common minimum stress. It should be stated that the weakening apparent from these tests cannot at this time be definitely ascribed solely to prior stressless-corrosion, since the added factor of inter-plate pressure due to the accumulation of corrosion products and restraining action of spring band was present. This point will be determined in the near future by prior stressless-corrosion tests on single plates tested at high frequency. However, the data presented do show material reduction in fatigue resistance due to some corrosion effect.

In summary it may be said that steel springs are highly stressed parts, usually subjected to very severe working conditions, and should be manufactured with modern and highly controllable equipment. Complete physical and metallurgical testing equipment and scientific testing procedure are essential to satisfactory spring service.



When Spring Steels or Assembled Springs Are Stored in Open or Otherwise Allowed to Corrode, Their Service Life at Given Stress Range Is Greatly Shortened. (Slope of curve is determined by more comprehensive tests in another series)

of service and laboratory exposures of multi-plate railroad springs are shown in a group of photographs taken at a magnification of 3 times. The section of all plates shown was $4\frac{1}{2} \times \frac{7}{16}$ in. The laboratory specimens were tested at a frequency of 50 cycles per min.

At top is shown the surface condition at the point of fracture on the tension side of an elliptic spring plate taken from railroad refrigerator car service after approximately one year exposure. It will be observed that the cracks originate in and progress from corrosion pits. This photograph illustrates an effect of stress corrosion on 1% carbon spring steel.

The middle view shows an effect of prior stressless-corrosion on chrome-vanadium spring

In Honor of Paul Dyer Merica



Photo by Blank & Stoller

Metallurgist and Executive

PAUL DYER MERICA is probably best known, here and abroad, for his contributions in the field of theoretical metallurgy, but his professional activities have been much wider in scope than this indicates. His associates recognize in him that rare combination of scientific training and precision of thought with organizing ability and an understanding of human nature; as a result science has lost a skilled investigator but industry has gained an able research engineer and administrator.

He was born in Warsaw, Ind., on March 17, 1889, the son of Charles Oliver Merica and Alice White Merica. Without doubt his interest in science was stimulated by his father, who was a clergyman and educator, later president of the University of Wyoming.

Paul Merica was educated at Depauw University and the University of Wisconsin; from the latter he graduated with the degree of B.A. in 1908. Subsequent to a year of post-graduate work in the department of physics, he traveled to China, where he became professor of chemistry in Chekiang Provincial College, Hangchow.

By careful saving during two years in China, he was able to finance two additional years of study. He went to Germany in 1911 for these advanced studies at the University of Berlin, where, in 1914, he received the degree of Doctor of Philosophy. Following his return to the United States he became a special investigator at the Engineering Experiment Station at the University of Illinois and, within a year, joined the staff of the Division of Metallurgy of the National Bureau of Standards in Washington.

In approximately five years, working under the late George K. Burgess, chief of the newly

formed Division of Metallurgy and later director of the Bureau, he acquired an international reputation. It was during this interval that he proposed an explanation for what was then the mysterious hardening of the new aluminum alloy called "duralumin," invented in Germany and used with such great success in the skeletons of the War-time Zeppelins. While his paper on the subject, prepared jointly with R. G. Waltenberg and Howard Scott, attracted more than ordinary attention, it was not until later that the significance of his theories—which are now commonly known as dispersion hardening or precipitation hardening in metals—became apparent.

It was while he was in Washington that he met and married his wife, Florence Young.

Merica's association with Dr. Burgess at the Bureau of Standards covered a period when the Division of Metallurgy was in an early stage of development. His scientific achievements, vision and leadership brought him to a prominent place in its rapid expansion and resulted ultimately in his being called to the Orford Plant of the International Nickel Co. in 1919 to be associated with its manager, A. J. Wadhams. Mr. Wadhams in 1922 organized the development and research department of this company at its New York office, and Dr. Merica joined him in New York in the new work.

In his new environment, first as director of research in the laboratory across the bay at Bayonne, N. J., and later as assistant manager of the development and research department, Dr. Merica played a prominent part in the development of broader uses of nickel in both ferrous and non-ferrous alloys. Probably his outstanding contribution during this period of

coordination between laboratory research and field work relates to alloy cast irons. He provided basic information relative to the metallurgy of alloy cast irons and, with his associates, helped to bring high quality irons into a more prominent place among the industrial alloys.

His consistent record of accomplishments in utilizing scientific methods for the benefit of industry forecast ultimately that he would be required to devote more of his time to administrative duties. In 1929 he was made assistant to the president, International Nickel Co. of Canada, where his attention was given not only to problems in the United States, but to activities in other countries as well. No doubt he finds useful in his present work reminiscences of his contacts and the conceptions gained in his early travels abroad while being educated and when teaching school. His further progress was marked by election in 1935 to the board of directors of the International Nickel Co. of Canada, Ltd., and, in 1936 to the post of vice-president.

A casual visitor to his office would probably characterize Paul Merica as an unassuming man with a most pleasing personality and gracious manner. But in a relatively short conversation he would be impressed by an analytical mind backed by scientific training and a broad experience, leading rapidly to a keen appraisal of problems and short cuts to their solution.

His honors are many. He was awarded the James Douglas Medal of the American Institute of Mining & Metallurgical Engineers in 1929 in recognition of distinguished service in the field of non-ferrous metallurgy and was honored again by the same society in his appointment as Institute of Metals Division lecturer in 1932. He is at present vice-president and director of the Institute. He has always taken an active interest in American Society for Metals and its predecessor American Society for Steel Treating, being a director in 1925-26, and at present a member of the finance committee.

In 1934 he was given the honorary degree of Doctor of Science by Depauw University. Dr. Merica is the author of numerous technical papers, and is a member of many engineering societies and technical committees. His hobbies are few, represented mainly by golf and music.

Powdering a Lead Alloy

By R. W. Rees

Condensed from *Journal, Institute of Metals*

METHODS of preparing metals in the form of powder may be divided roughly into the following classes: (a) Reduction of the oxide with hydrogen, (b) precipitation of the metal from solution, (c) distillation, and (d) mechanical disintegration. Mechanical disintegration is usually the only practical method for alloys; this presents considerable difficulty in case they are ductile.

For a particular purpose, an alloy with a melting point not exceeding 350° F. was required in the form of powder to pass a 200-mesh sieve. The composition was unimportant, provided that it could be produced cheaply, and this necessitated lead as the main constituent.

Most alloys containing more than 50% lead are so ductile that they cannot be powdered by crushing or grinding. Even the comparatively brittle lead-antimony alloys are too soft in this respect, and attempts to induce intercrystalline brittleness by additions of elements like sulphur were not satisfactory.

Success was finally attained by using alloys having a wide interval between liquidus and solidus, in which range they have a consistency of wet sand, and can be broken up into coarse powder by simple agitation. The composition of alloys possessing this property can vary over a wide range; an alloy of lead 50%, cadmium 30%, and tin 20%, having a freezing range from 350 to 300° F. was found particularly suitable for powdering.

The method adopted was to feed the pasty metal into an impeller-type disintegrator maintained at a temperature about 20° F. below the solidus. The body of the mill was 10 in. diameter by 3 in. wide; once up to temperature the heat introduced with the hot charge was sufficient to maintain operations satisfactorily.

The shaft carrying the blades was driven at a speed of about 1500 r.p.m. The metal screen forming the bottom of the mill had perforations 1/64 in. in diameter. The yield was all through 70 mesh, 80% 100 mesh, and 30% 200 mesh. The product, which discharged into a bag, was sieved through the appropriate screen, any over-size being returned to the heated hopper. The output of such a mill is about 200 lb. of 200-mesh powder per day.

A nickel-aluminum compound is shown to be soluble in gamma iron at high temperature but insoluble in alpha iron at low temperature, and therefore has possibilities as a hardener for steel by a solution and precipitation treatment

Nickel-Aluminum Compound A Hardener for Steel

■ IN THE LAST TWO ISSUES OF METAL PROGRESS have appeared first a discussion of the historical development of the general hardening theory, and second a brief statement of its application to the quenching of carbon steel. The latter is by all means the most important phase of the subject, and one of the articles ended with a statement that while we can harden iron with other alloys and in other ways, it is doubtful if anything will be found quite as useful a hardener as carbon, or any process quite as convenient as quenching and tempering.

However, not all the changes which occur in the hardness of steel can be explained on the basis of the principles outlined last month. For instance, much of the steel sheet designed for deep drawing purposes, which is quite low in carbon, and has never been quenched and tempered, has the disturbing tendency of gradually becoming harder and losing ductility with time, even at room temperature and to such an extent as to interfere with its economical fabrication. A comprehensive review of this phenomenon was given by E. S. Davenport and E. C. Bain in their paper on "The Aging of Steel" before the Chicago Convention, A.S.M., last year.

Another instance is the effect of copper when

alloyed with steel. As pointed out by C. H. Lorig in METAL PROGRESS last April, copper steels harden while aging at moderate temperatures. This is a matter that will force itself into attention, willy-nilly, for the amount of copper in the circulating load of scrap (the principal raw material of basic open-hearth steel) is gradually increasing, already being about 0.25% in the "plain carbon steel" produced in the Detroit district.

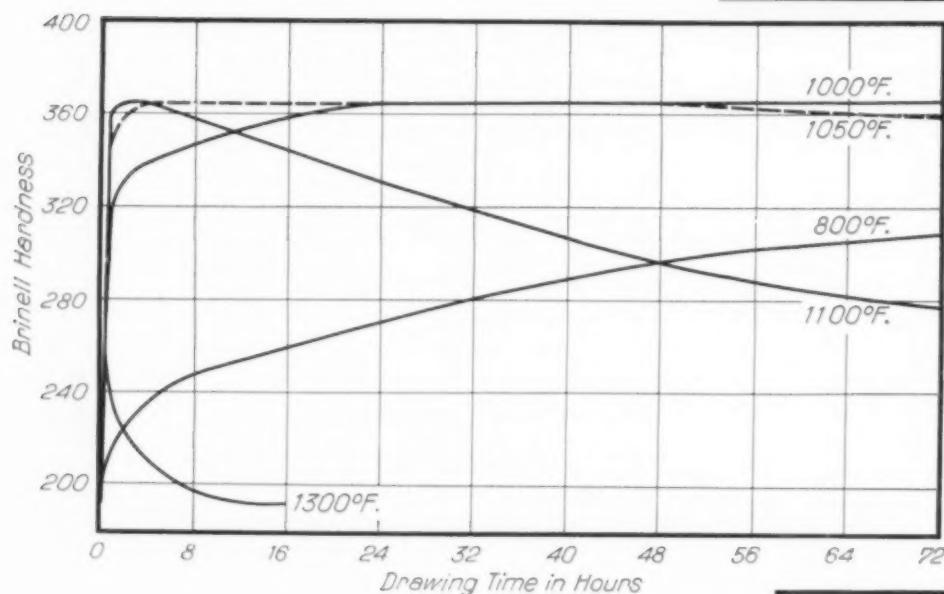
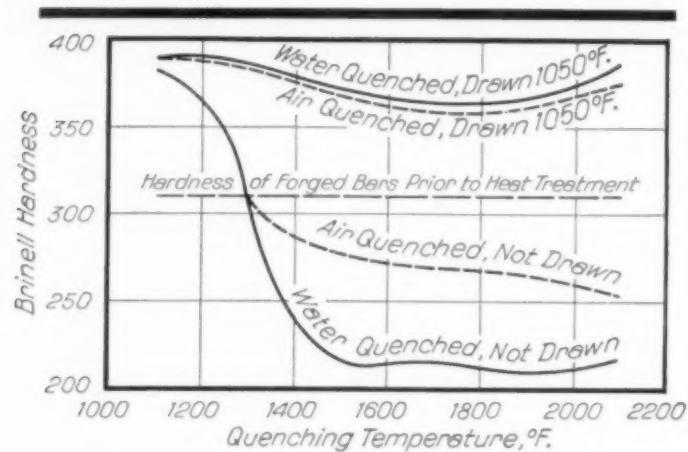
It is now desired to elaborate somewhat on the phenomenon just mentioned — namely that some iron alloys are not nearly as hard immediately after quenching as they are after a subsequent exposure to moderate temperature. Such phenomena are generally ascribed to gradual precipitation of some constituent held in solution during the quench; that is to say to "precipitation hardening." A case in point was studied in the laboratories of The Midvale Company; in treating a nickel-chromium-aluminum steel it was noticed that hardening resulted from reheating in the neighborhood of 1000° F., following a previous cooling from a temperature below the critical temperature of the steel where carbon goes into solution.

Elimination of chromium from the analysis showed that the phenomenon still persisted. Upon removal of carbon from the composition as completely as practicable, the resultant nickel-aluminum-iron alloy still hardened considerably. Upon the removal of the nickel from the composition, hardening no longer was possible in the remaining aluminum-iron alloy.

By Francis B. Foley
Superintendent, Research Dept.
The Midvale Company
Philadelphia

A nickel-aluminum-iron alloy which well serves to illustrate how such metal responds to hardening by precipitation was cast from a high frequency induction furnace in the form of a 4-in. square ingot weighing 30 lb. It had the following composition: Carbon, 0.03%; manganese, 0.16%; silicon, trace; nickel, 5.03%; aluminum, 2.59%.

The ingot was heated to 2050 to 2075° F. for hammering to $\frac{1}{2}$ -in. square bars and specimens



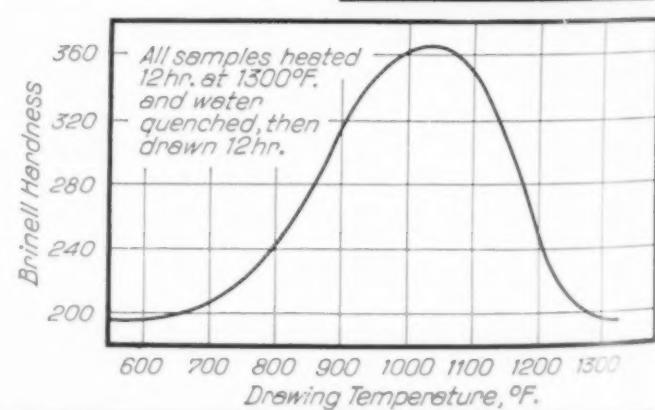
Three Studies of Precipitation Hardening in a 5% Nickel-Iron Alloy Containing 2.59% Aluminum. At top: The hardening compound is put completely into solution in 15 min. at 1500° F. or over, and retained there by water quenching. Drawing 5 hr. at 1050° F. nearly doubles the hardness . . . Above: Solid solution alloy is hardened very rapidly by precipitation at 1100° F. but slightly lower temperature is necessary to avoid softening by "over-aging" . . . At right: Maximum hardness is achieved after aging 12 hr. at 1050° F., specimen having been given adequate solution treatment

were cut to length for treatment. The hardness of the bar after cooling from the forging temperature was Brinell 309.

It was deduced from the previous work that a nickel-aluminum compound was participating in the hardening reaction, and its solution temperature in this alloy was between 1050 and 1100° F. (considerably below the A_{c_1} point for carbon in steel.) Therefore, quenching experiments were started at 1100° F., and then in steps of 100° up to 2100° F., duplicate specimens being heated for 15 min. to each temperature. Following quenching (one specimen in air and the other in water from each temperature) they were all drawn at 1050° F. for 5 hr. and their Brinell hardness determined. The results are shown in the top diagram.

The effect of time was immediately noted in the samples air or water quenched from 1100 and 1200° F. The intermediate value of hardness in the forged condition was attributed to the retention of some nickel-aluminum compound in solution in the hammered material; some of this was liberated during reheating to 1100 and 1200°,

but the 15-min. holding time was not sufficient to permit its reabsorption before the sample was removed and cooled. At higher quenching temperatures there was absorption of the compound, practically complete at 1500° F. and higher. The compound evidently was completely retained in solution by water quenching, but not completely by air cooling — hence the harder samples after air cooling. Where practi-



cally complete solution was attained by water quenching there was an increase of approximately 150 Brinell points in hardness as a result of precipitation during 5 hr. reheating at 1050° F.

In order to get the effect of time on this hardening reaction a solution heat treatment of 1300° F. was used. Specimens were quenched in water after a 12-hr. hold, following which they were drawn for various lengths of time, from 15 min. up to 72 hr. at 800, 1000, 1050, 1100 and 1300° F. respectively. The results are given in the middle graph.

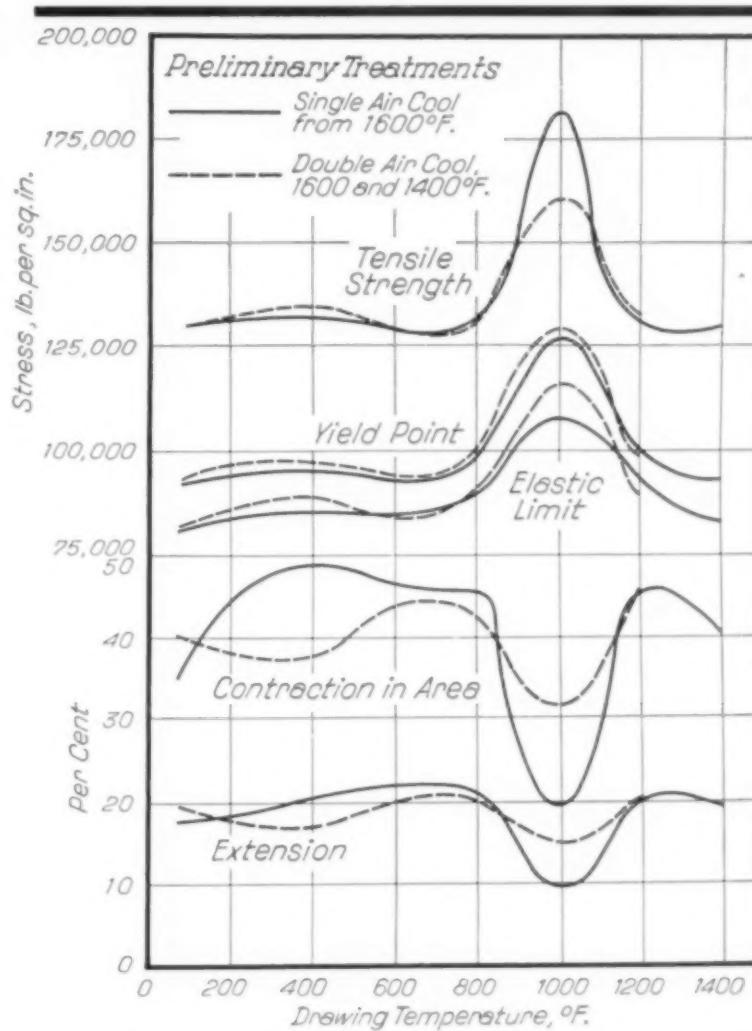
Quenching in water following a hold of 5 hr. at 1300° F. gave a softer sample than any of those in the former experiment, namely Brinell 195. Full hardening is not attained in drawing at 800° F. in 72 hr., the trend of that curve being still upward. At 1000° F. 24 hr. is sufficient, and there is apparently no redissolving of the constituent, resulting in softening, in 72 hr. at this temperature. As the temperature of precipitation increases, full hardness is obtained in shorter times (1 hr. or less at 1050° F.), and upon holding for prolonged periods re-solution or growth of the hardening particles and decrease in their number occur with a lowering of the hardness. At 1100° F. full hardening occurs in an hour or less, but softening then immediately sets in. At 1300° F. precipitation and re-solution occur simultaneously.

The effect of temperature of aging, other things being constant, is shown in the bottom curve on page 54. A solution treatment of 1300° F. for 12 hr. was used, quenching in water, and re-treating for 12 hr. at 100° intervals between 600 and 1300° F. Under these conditions maximum hardness was induced by precipitation at 1050° F.

That aluminum alone is not responsible for this hardening is shown by experiments on a heat of the following composition: Carbon, 0.05%; manganese, 0.57%; silicon, 0.19%; aluminum, 3.12%. After forging, this composition had a Brinell hardness of 156. Specimens were quenched in air, oil and water from 1300, 1500, 1700, 1900 and 2100° F. after holding at temperatures for 30 min., and were then reheated to 1000° F. for 60 min. Softening resulted in every case. There appears

no question concerning the fact that a nickel-aluminum compound is the cause of the hardening in the particular nickel-aluminum-iron alloy under discussion.

Copper and molybdenum were tried in place of nickel. Neither seems to have, in the amounts used, the hardening power of nickel. For instance, a copper alloy analyzed carbon, 0.05%; manganese, 0.40%; silicon, 0.23%; copper, 3.15%; aluminum 2.49%. The forging and heat treating routine was similar to that already described. The quenched hardness was Brinell 206; maximum hardening occurred after quenching from 1500° F. and drawing 60 min. at 900° F., and this was only Brinell 255. A molybdenum alloy contained carbon, 0.10%; manganese, 0.10%; silicon, 0.33%; molybdenum, 9.58%; aluminum, 2.46%. Its hardness quenched was Brinell 363; aged it



Tensile Properties of Valve Steel After Solution Treatment and Drawing at Various Temperatures. Unusual properties exist after drawing at 1000° F. Composition: 0.50% carbon, 0.36% manganese, 0.94% silicon, 1.58% nickel, 10.66% chromium, 1.77% aluminum

was only 415 (1200° F. for 60 min. after a 1300° F. quench).

Interesting results were obtained by using the above principles in a series of experiments on a complex steel suitable for gas engine valves. A typical analysis is carbon, 0.50%; manganese, 0.36%; silicon, 0.94%; nickel, 1.58%; chromium, 10.66%; aluminum, 1.77%. Ends of the valve stems of such steels are hardened by heating locally (as with an oxy-acetylene torch) and cooling in air.

The A_{c_1} critical temperature for carbon in this steel is in the neighborhood of 1700° F. A series of experiments was made on samples which had either been air quenched from 1600° F., or double quenched from 1600° and 1400° F., both times in air. The curve sheet on page 55 shows the tensile properties of such a steel after draws at successively higher temperatures at 100° F. intervals from 200° up to 1400° F. Note how the tensile strength of 130,000 psi. after the solution quench at all other drawing temperatures, sharply increases in the 800 to 1200° F. range, reaching a maximum of 180,000 psi. at 1000° F., due to precipitation of the nickel-aluminum compound.

When the nickel content of such a steel is increased to 2.83% and the aluminum to 3.47% (as in a composition carbon, 0.66%; manganese, 0.63%; silicon, 0.88%; nickel, 2.83%; chromium, 11.30%; aluminum, 3.47%), an alloy is produced which is rendered austenitic and non-magnetic by quenching from 2000° F. or above. Peculiar results are obtained upon reheating this austenite as shown in the table on this page.

Treatments were superimposed for each specimen where Brinell hardness readings are given in the table; that is, specimen C was first given treatment I and tested; then treatment IV and tested, and finally the same specimen received treatment V. All specimens were first given a 30-min. soak at 1600° F. and cooled in air; a medium hardness was the result (Brinell 307 to 319°). It is noted that a 2200° F. quench produces a soft, practically non-magnetic austenite—see specimens A and B, treatment I followed by treatment II. Heating at 1000° F. for 1 hr. does not appear materially to transform the austenite, since specimen A remains soft and non-magnetic after treatment III. Reheated at 1300° F., hardening occurs, Brinell increasing from 197 to 363 in specimen B (treatment I plus

II plus IV). Now if this martensitized steel specimen B is reheated to 1000° F., the hardness further increases to 444 Brinell, but no increase in hardness is noted in the austenitic specimen A upon repetitions of the 1000° F. heat. Specimen D, simply air cooled from 1600° F., is also hardened to 444 Brinell by a reheating to 1000° F.

From these results it appears that the nickel-aluminum compound is soluble in austenite, but

Cumulative Heat Treatments on Cr-Ni-Al Valve Steel

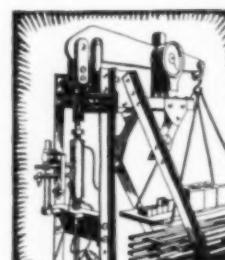
No.	Temperature	Time	Quench	Heat Treatment		Brinell Hardness of Specimen		
				A	B	C	D	
I	1600° F.	30 min.	Air	311	319	307	312	
II	2200	10 min.	Water	187*	197*			
III	1000	1 hr.	Water	202*				
IV	1300	1 hr.	Water		363	321		
V	1000	1 hr.	Water	187*	444	444		
VI	1000	1 hr.	Water	207*	477	—	444	

* Practically non magnetic

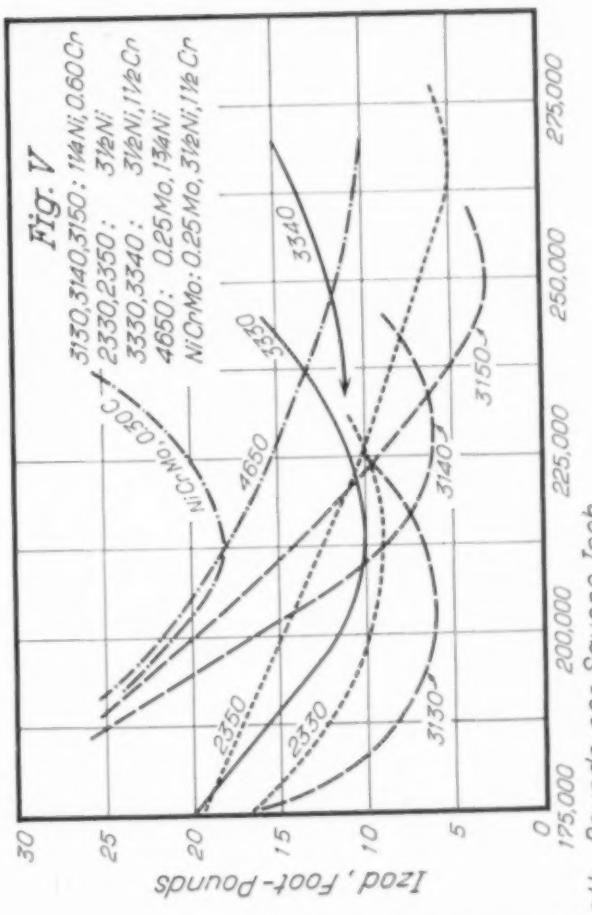
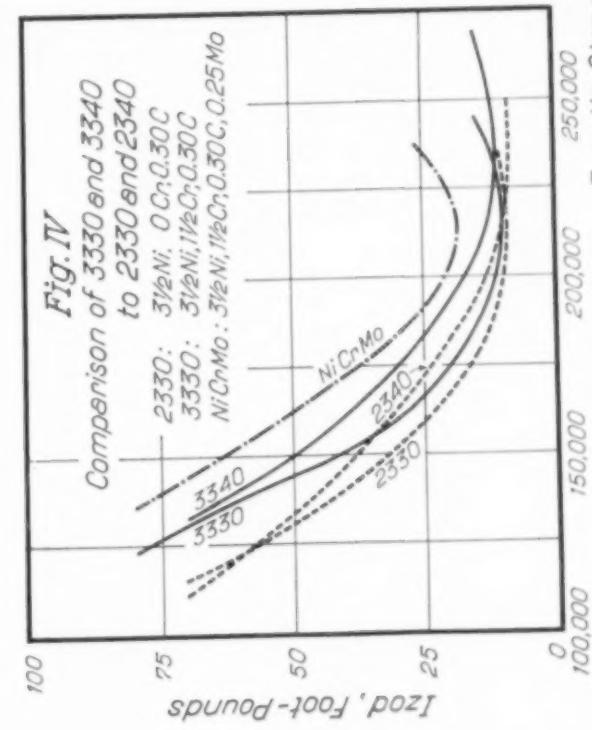
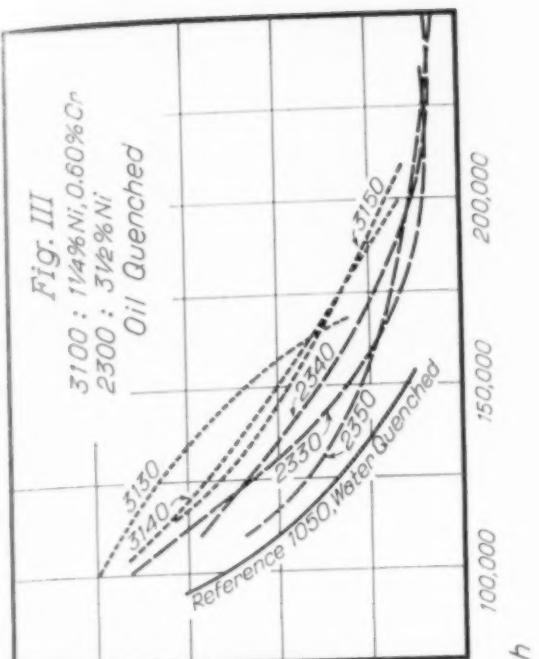
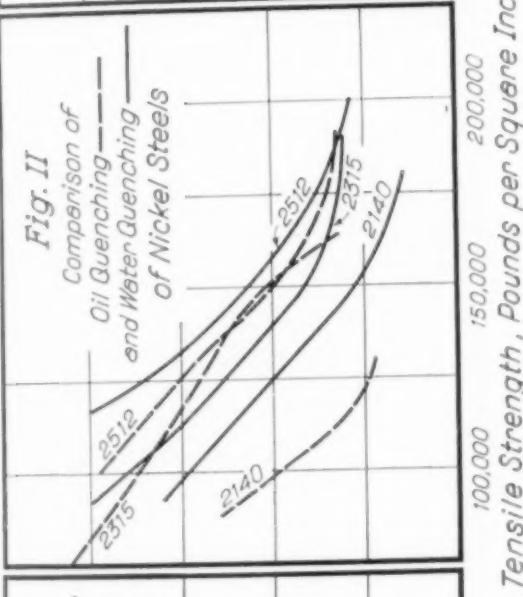
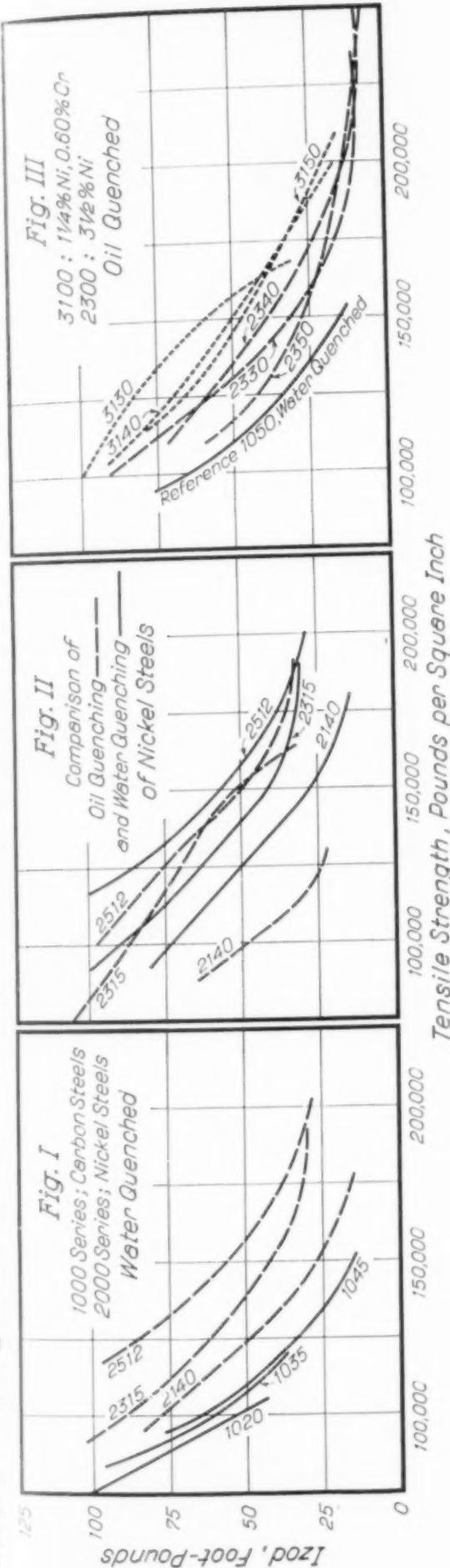
not in alpha iron. Not until a transformation to alpha iron has occurred will it be precipitated from a steel which has been rendered austenitic.

The temperature producing maximum hardness by precipitation of the nickel-aluminum compound—approximately 1050° F.—is interesting. It is close to that for maximum secondary hardening of high speed steel and is not far above the usual temperature for nitriding. The coincidence of these temperatures suggests the possibilities of practical application of the phenomenon. Nickel-chromium steels which are normally austenitic may have their hardness increased, when aluminum has been added to the composition, by the precipitation of nickel-aluminum compound. When this happens it will be observed that the precipitation takes place in the alpha (delta) iron introduced by the presence of the aluminum.

The use of steels containing nickel-aluminum for nitriding has led, I believe, to an increase in the hardness of the nitrided surface—due largely to the increase obtained by precipitation in the metal underlying the nitrided surface.



Izod Toughness Vs. Tensile Strength of Heat Treated S.A.E. Steels



Alloy steels may be appraised by comparing their ratios of toughness to ultimate strength. The above charts do this for some of the familiar S.A.E. steels; the data have been reprinted by Ernest E. Thun from the excellent handbook on "Nickel Alloy Steels" published by International Nickel Co.

Figures I and II indicate that 0.20 to 0.45% carbon steels are about equal in Izod impact when heat treated to equal strength. Nickel increases the toughness-to-strength ratio materially, especially at high strengths. Figure III shows how a little chromium strengthens the tough nickel steel to

about the highest toughness-to-strength ratios available (Fig. IV showing that 1.5% Cr adds 13,500 psi to the tensile for equal Izod figures throughout the range 15 to 70 ft-lb.). Nickel-chromium-molybdenum steels are remarkable, as can be seen in Fig. V showing toughness at high strength.

One of the points in a wave of propaganda was that sterility was bound to result from exposure to the glare of the arc or from breathing gas from coated electrodes.

"It must be true," reasoned the believers, "else why is Hejaz childless after eight years of marriage?"

And then one bright day it happened! Hejaz' wife presented him with a fine son! An amazing contradiction it was; but the die-hards had to see to believe. Away they went in crowds to Hejaz' house, there to be shown the offspring!

But, on the other hand, many, many native workmen have become welding operators. Some are quite efficient if the current and rod sizes are set for them. They do straight welding all right but just let them tackle something out of the ordinary, on their own, and trouble starts.

Take, for instance, the native in Honduras, Central America. The local welding shop had received a shipment of "Ferroweld" electrodes, manufactured by the company with which the writer is connected, for welding cast iron. The welders (native included) were instructed fully on the use of the new rods. While the foreman was away from the shop, the native welder was asked if he could do a certain job which needed them—a steel hook was to be welded to a 10-in. cast iron ram for a hydraulic press.

"Seguro, Señor, I can weld it," said the native, and with that he started to work.

Layer by layer he built up the weld to the required size. Why was it that the steel hook just fell off the casting after three hours' work? Here's the native welder's answer as to whether he had followed instructions:

"I'm working twelve years in this welding

shop and had never trouble with electric welding! Why should I reverse the cable and wait until the work is cool enough before I start the second weld?"

And then there was the case, in an Asiatic country, of the native who struck an arc on an acetylene generator in starting to repair a leak! A week was spent looking for every bit of him for burial, to satisfy the Mohammedan belief that a person cannot enter paradise if any part of his body is missing.

Aside from getting into occasional difficulties — sometimes more ludicrous or exasperating

than important — and reacting variously to the electric arc, the native workman, in most instances, can be taught to weld. He even becomes fairly proficient after considerable training and repeated demonstrations on the part of the foreman. But the principles of the process always remain a mystery; the native ability is purely mechanical.

Once given an opportunity to become a welder, the natives, regardless of creed or country, are exceedingly proud of their position. They wear their helmets continually, at home, or on the job—some even wear them to sleep. Whatever else the electric arc is to natives in foreign lands, it is the symbol of highest honor. More than anything else does the native want to be called in his mother tongue—or even in English—"arc welder."

Pride in his ability is the first essential for a good artisan, either in a civilized, nomadic or savage community. However, the greatest native ability would not avail if rugged, automatic generators and metallurgically-balanced electrodes were not at hand. Penetration of welded pipe lines into almost inaccessible regions is proof that these requirements have been met.



Two Products of far-off Vizagapatam, India — an Arc Welded Impeller for a Gold-Field Dredge and a Native Workman

A portion of a new section for the 1936 Edition of American Society for Metals Handbook is reproduced below. This portion covers the acids and inhibitors used, and the technique of an economical operation

Notes on the Efficient Pickling of Iron and Steel

PICKLING is the term applied to the chemical removal of surface oxides from metal by immersion in an acid solution. An instance is removing mill scale formed at comparatively low temperatures during or after hot rolling on low carbon steel. Removal of such scale is one of the simplest of the cleaning problems. The material is submerged in warm, dilute sulphuric acid until free from scale, after which it is removed and rinsed clean.

Although pickling appears to be a simple process, numerous refinements or modifications are necessary in many instances. Because of the broad influence of sometimes obscure variables in scale formation and because of the difference in processing practice and equipment encountered even in two plants making the same product, it is not practical to reduce pickling procedure to a standard formula. Therefore, the procedures to be described are merely the methods found successful in plants producing the particular material under discussion.

Cleaning prior to pickling is often quite as important as the operation itself. The iron or steel is frequently covered with grease; hot alkali solutions are generally satisfactory for cleaning

such material, but should always be followed by careful rinsing. Another cleaning method is to heat the metal to a moderately high temperature for a short time.

When low carbon steel is pickled for enameling, galvanizing or tinning, special precautions are necessary to insure a surface which is chemically clean as well as free from scale. (A slightly but definitely etched surface is often believed to permit greater adherence of the coating.) In this case inhibitors or foaming agents can be used in the bath only with proper precautions since some leave a thin but very tightly adherent surface film.

The trend in recent years is toward lower pickling temperatures, around 150 to 160° F., resulting in economy in steam consumption and in better quality of the finished product. Where time and pickling capacity permit, an acid concentration of 5 or 6% is advisable. The usual practice, however, where comparatively low temperatures are used, is to compensate for decreased thermal activity by raising the acid concentration to about 10 or 15%. In continuous sheet or strip mills provision is usually made for continuous pickling so that fabrication can proceed without interruption. Control of the rate of pickling is then accomplished by varying the temperature or the acid content of the bath. Both are frequently kept too high for best economy or quality in order that the operation may be completed in the time allowed and synchronized with the rolling mill.

By C. H. McCollam
and D. L. Warrick
Chief Chemist and Research Chemist
Timken Steel & Tube Co.
Canton, Ohio

Specialized Products

In pickling for galvanizing or tinning many plants use two pickling baths; first a 5 to 10% solution of sulphuric acid in water at 150 to 190° F. and second, a short-time dip in cold concentrated muriatic acid (18 to 20° Baumé) or in a moderately strong solution of muriatic acid at a somewhat elevated temperature. (Hot muriatic acid evaporates and fills the atmosphere with noxious fumes.)

Vigorous mechanical agitation of the bath is always advisable. When it is stagnant, gas pockets tend to form which keep the acid out of contact with the metal; when the steel is galvanized, these scale-retaining areas remain uncoated. Agitation also secures uniform acid concentration throughout the bath, assuring a more nearly uniform rate of pickling.

When pickling sheets for galvanizing or tinning, as short a time as possible should elapse between pickling, rinsing, and coating operations. Should a minor delay occur between rinsing and coating the material should be stored under water and never allowed to dry, else it will rust. Furthermore, any ferrous salts from the pickling bath which dry on the work oxidize and are difficult to remove.

High acid concentration is advisable for pipe or seamless tubes, particularly those of small inside diameter, since the acid solution which first enters the tube must often be relied upon to complete the pickling of the inside surface. Occasional lifting of the bundle above the bath to drain the spent acid out of the tubes helps to overcome this difficulty. Jets of air or steam directing a current of pickling solution through the tubes, and mechanical rockers are sometimes valuable aids.

Heat treated material introduces many special pickling problems. It has been demonstrated that when alloy steels are heated above certain critical temperatures which vary with the type, an electrolytic action is set up between the scale and steel. This action results in serious pitting. Inhibitors have been found to be of little value in preventing such pitting. Normalizing scale represents the worst condition, while temper scales are the easiest to handle. Best results will usually be secured by using a fresh bath of 8 to 10% sulphuric acid (inhibited) with a temperature of between 145 to 155° F., and providing mechanical agitation.

Forging scale formed at elevated temperatures is likely to be thick, glassy and extremely adherent. Some is frequently knocked off while

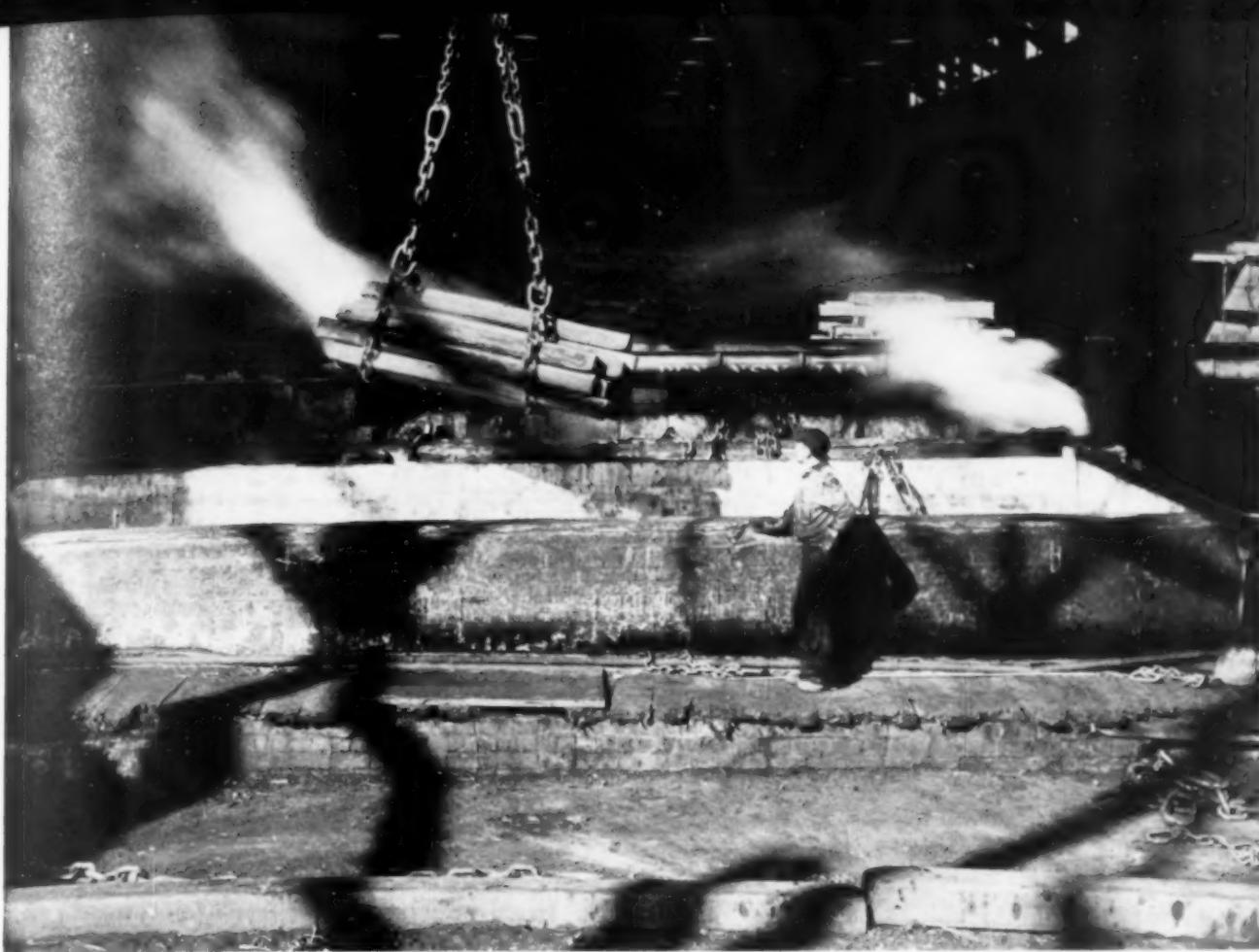
handling, leaving small exposed areas of metal. At such places deep pickle pitting is likely to occur. However, the mechanical removal of as much of the scale as possible either before or during pickling decreases pitting. Pickling in 8 to 15% sulphuric acid at 150 to 160° F. has been found to give good results.

Stainless steels present a special problem because scale containing high percentages of chromium oxides is not readily attacked by sulphuric acid alone. A common practice is to employ a mixture of about 10% sulphuric acid with 2 to 10% muriatic acid, or a mixture of 10% sulphuric acid with about 10% common salt. In the latter case, muriatic acid is generated by reaction between the sulphuric acid and the salt. Muriatic acid alone is sometimes used. In any case pickling is followed by a bright dip in 5 to 50% HNO_3 (by volume); the more dilute solutions of this acid are generally used warm while the higher acid concentrations should be used cold to avoid damage to the handling equipment. Thorough rinsing in hot water, sometimes augmented by scrubbing, is essential to best results.

Acids and Acid Mixtures

Pickling solutions generally used are sulphuric, muriatic, nitric and hydrofluoric acids, or mixtures thereof. Sulphuric is the cheapest and most commonly used. Muriatic is used for special purposes such as etching prior to galvanizing or tinning and sometimes for stainless steel. Nitric acid is used for stainless steels and occasionally employed to oxidize scaled surfaces to facilitate pickling. Hydrofluoric acid is sometimes added to the bath to accelerate pickling, and is used occasionally in pickling castings to remove sand.

The action of pickling solution on metal is in nearly direct proportion to the acid concentration up to about 25% of acid by weight. The concentration depends upon the kind and temperature of acid, the type of material being pickled, and the surface desired. Thus, when sulphuric acid is used on mild or pearlitic alloy steels the maximum concentration is 20 to 25% and the optimum is 8 to 10%. For pickling tubes and pipe a high acid content should be maintained because the solution on the inside of the tube does not circulate, and consequently becomes depleted before the scale is removed if weak acid is used. Muriatic acid solution is held from 5 to 50% by volume; the higher concentrations cause definite etching of the surface. Nitric acid is used in amounts of from 5 to 50% by vol-



Tanks for Pickling Billets Must Be of Substantial Construction to Withstand Accidental Bumps From Heavy Bundles. Concrete, lined with paving brick set in a mortar of melted sulphur mixed with clay has given good service

ume; concentrated solutions passivate steel surfaces. The fumes from nitric acid pickling are dangerous and adequate ventilation should be provided.

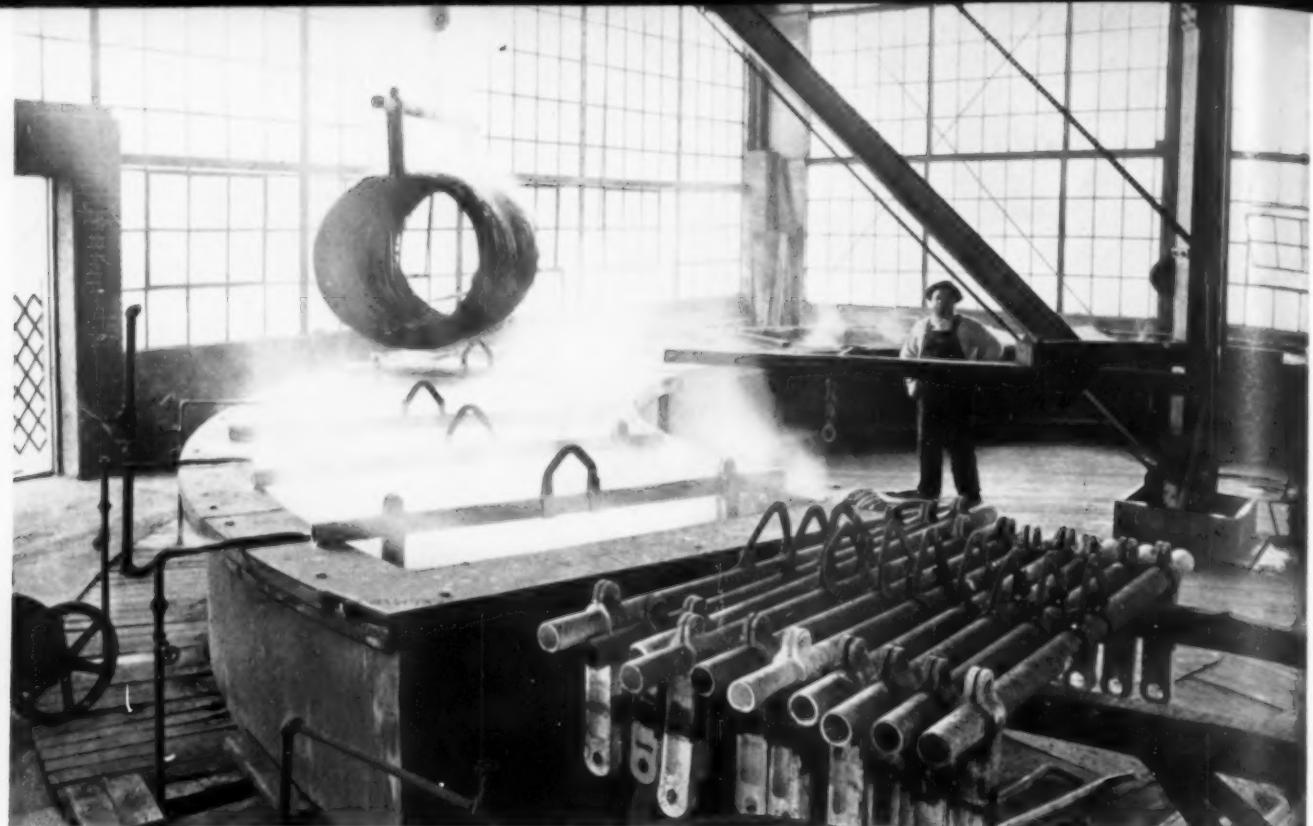
Testing of pickling solutions is a very important part of supervision yet one which is frequently overlooked. Pickling tanks should be sampled regularly. It is a good plan to take a sample from each acid tank early in every turn. In the pickling of sheets, the acid strength should be determined after each lift in batch pickling and every half-hour in continuous pickling. For testing a sample can be titrated with standard solutions; the use of a hydrometer is not recommended, due to variations in gravity introduced by the ferrous sulphate content. The following procedures can be used for titrating the various solutions.

Determination of sulphuric acid content: Measure out 5.0 cc. of the solution into a 200-cc. flask. Add 25 cc. of water and two drops of methyl orange solution. Add standard sodium carbonate solution until the last drop causes the color to change from red to yellow. Each 5 cc. of the sodium carbonate solution equals 1% of sulphuric acid in the pickling tank. (This simple rule, which is sufficiently accurate for commercial purposes, is based on the specific gravity of 10%

sulphuric acid.) To make up the standard sodium carbonate solution, dissolve 11.52 g. of dried c.p. sodium carbonate in 1000 cc. of distilled water. (This standard solution is slightly stronger than N/5 sodium carbonate solution, which may be substituted without appreciable error in commercial practice.) Methyl orange solution may be made up by adding 1 g. of methyl orange powder to 1000 cc. of distilled water. This solution should be kept in a dropping bottle.

When the pickling solution is muriatic acid the determination may be carried out in exactly the same manner as outlined above except the final calculation. In this case each 5 cc. of the standard sodium carbonate solution equals 2.07% by volume of 20° Baumé muriatic acid or 2.36% by volume of 18° Baumé acid, each of these values being equivalent to 0.755% by weight of hydrogen chloride (based on the specific gravity of 10% hydrochloric acid).

For determination of iron content, 5 cc. of the solution is placed in a 200-cc. flask and diluted with 5 cc. of water. Standard potassium permanganate is added from a burette until the last drop turns the solution to pink. Each 5 cc. of standard permanganate solution equals 1% of iron or 5% of ferrous sulphate. The pink end point fades quickly when organic inhibitors



Handling Wire Bundles in Curved Tanks Arranged About a Jib Crane. Steel tanks, brick sheathed and rubber lined, are satisfactory for most uses. (Photo courtesy B.F. Goodrich Co.)

are present; therefore, the titration should be rapid. The standard permanganate solution can be made by dissolving 6.01 g. of c.p. potassium permanganate in 1000 cc. of distilled water. (This standard solution is slightly weaker than N/5 potassium permanganate, which may be substituted without appreciable error in commercial practice.)

Acid Additions — The acid content in the tanks should be maintained at all times above the minimum found to be practical for the material being pickled. For mild carbon steel and most alloy steels this would be about 5% of sulphuric acid. Acid additions should be made frequently and in small amounts to hold the bath uniform. If consumption is to be accurately established, the acid addition must be carefully measured, either by metering or by a measuring tank. When additions are recorded as being so many "minutes of acid" through a pipe, there are generally variations due to the amount of acid in the storage tank, the air pressure on the acid line and other factors.

The damping effect of ferrous sulphate on pickling efficiency is well known. The ferrous sulphate content of a bath is five times the iron content; and it has been demonstrated that with 40% ferrous sulphate (8% iron) the rate of attack of sulphuric acid on steel is reduced by half. It is common practice to run the bath up to 25% ferrous sulphate (5% iron), and then use the solution without further additions until the acid con-

tent is reduced to less than 5% and dump the tub.

The practice of dumping waste pickle solutions into sewers and streams has resulted in stream pollution. Legislation has been introduced in many states requiring the neutralization of pickling acid before disposal. Small plants will find it economical to kill the spent acid with lime in settling basins.

Pickling Temperatures — Heating is generally accomplished by introducing live steam through an open or perforated lead pipe. Temperatures can be taken at intervals by an ordinary thermometer or by indicating or recording instruments. Temperature controls are available for installations where temperature variation must be held to a minimum.

The effect of temperature on chemical activity is generally recognized. Sulphuric acid at 190° F. has over a hundred times the solution rate of the same acid at room temperature. However over-pickling is likely to occur at high temperatures. Inhibitors are important factors in establishing the limiting temperatures, since some inhibitors fail rapidly at high pickling temperatures.

While a temperature of 170 to 190° F. is sometimes satisfactory when the time cycle is short, pitting may result if the pickling period is prolonged. With many high carbon and alloy steels a pickling temperature of 140 to 150° F. has been found to be satisfactory for efficiency, surface quality and inhibitor life.

Pickling Inhibitors

Inhibitors are agents added to an acid pickling bath to diminish the attack on the metal areas from which the scale has been removed, without appreciably retarding the rate of scale or rust removal, and to diminish the severity of hydrogen embrittlement.

Advantages and disadvantages of acid inhibition may be briefly stated as follows:

Advantages: (1) Reduces metal loss; (2) saves pickling acid; (3) prevents or minimizes scrap losses resulting from over-pickling; (4) decreases blistering and hydrogen embrittlement.

Disadvantages: (1) Increased pickling time; (2) possibility of residual surface film which may interfere with subsequent operations; (3) added cost of inhibitor.

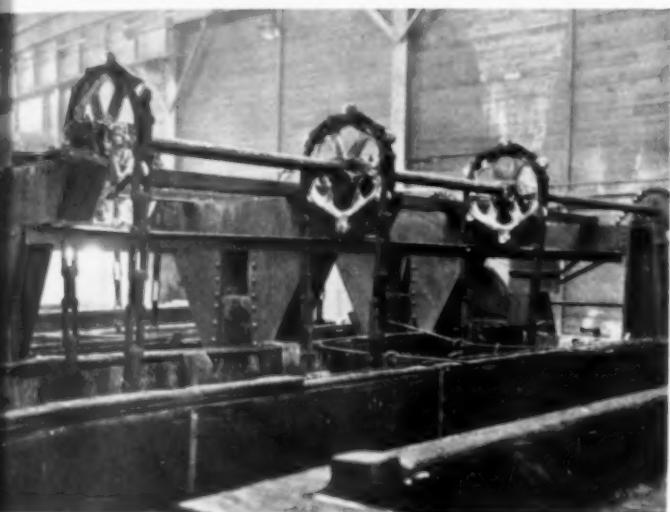
Various observers have stated that inhibitor action seems to be associated with an increase in the hydrogen overvoltage at the metal surface. A protective coating of hydrogen is thereby maintained on the metal surface (cathodic areas in an electrolytic couple) which helps to protect the metal from direct contact with the acid, thus diminishing the attack.

Another theory is that a thin layer of inhibitor material is adsorbed or plated out on the surface of the metal. Many of the known organic inhibitor solutions are colloidal in nature, which lends support to the possibility of either adsorption or cataphoretic migration of inhibitor particles. On the other hand, such a layer, if existent, is so extremely thin as to escape detection in many instances.

A wide variety of materials have been advocated and used as inhibitors, from cabbage leaves or wheat bran to complex synthetic organic chemicals. In numerous instances raw materials and by-products have been useful, and many are still being used without the separation or identification of the active ingredient. A comprehensive list would be difficult to prepare, but would include the following: Sludge acid from oil refineries, waste animal materials, waste sulphite cellulose liquor, wheat bran or off-grade flour, sulphonation products of such materials as wood tar, coal tar, and asphaltum. These materials vary widely in their effectiveness and uniformity, yet they have an economic advantage and are not necessarily inferior to synthetic inhibitors.

A wide range of synthetic chemicals have been reported as showing inhibitive properties. Many of these are extremely complex in structure and high in molecular weight. Aldehydes, thioaldehydes, mercaptans and other sulphur-containing organic compounds, organic nitrogen bases and their derivatives, particularly those in which the nitrogen is linked within a heterocyclic ring, such as pyridine and quinidine, seem to be favorites. Their cost often precludes their use for production work. Some of these compounds are so efficient, however, that extremely small amounts are required.

Foaming Agents — The function of foaming agents is to blanket the surface of the pickling solution with a suds which traps and holds any fine spray of acid that would otherwise be carried into the atmosphere with the hydrogen gas evolved. Their chief advantage lies in preventing pollution of the atmosphere. Some confusion exists about the relation between inhibitors and



By Bar Stock and Especially Small Tubes Require Constant Rotation for Uniform Pickling Without Pitting. View shows tanks in cradles and central elevating mechanism at Timken Steel & Co. Double-walled wooden tanks of cypress or long-leaf pine with asphaltic inter-lining and are bound with monel metal bolts

The actual mechanism of inhibitor action is not well understood. Some investigators believe that inhibitors are "negative catalysts" which are selective in action, retarding the reaction of acid on metal but not on scale. In practice no inhibitor continues its original effectiveness unabated throughout the entire pickling cycle. However, they lose efficiency so slowly that the loss could hardly be attributed to reactions in which the inhibitor plays a major part as reagent. The effect seems analogous to what is called poisoning.

foaming agents. Actually they represent independent phenomena, although in many preparations they are co-existent. With a sufficient quantity of a good inhibitor, the evolution of hydrogen is so small that a foaming agent is unnecessary.

Testing of Inhibitors—While the ultimate test is their behavior in the pickling bath, laboratory tests offer a convenient means of comparing the value of inhibitors under carefully controlled conditions. These are of two general types: (1) Those which measure the loss in weight of metal in inhibited acid, and (2) those which measure the amount of hydrogen evolved. The latter depends on the fact that when metal reacts with a non-oxidizing acid hydrogen is evolved, but when the acid reacts with metallic oxide, water is formed with no gas evolution. Hence a theoretically perfect inhibitor would allow removal of the scale with no evolution of hydrogen.

Inhibitors frequently fail in service due to localized overheating where steam is introduced into the bath. Laboratory tests should take this fact into consideration. A satisfactory check may be secured by refluxing a sample of the inhibited pickle solution for not less than one hour. Because of the wide difference in the acid solubilities of high and low carbon steels, inhibitor efficiency tests should be made on the same grade of steel as will be treated in the pickle tub.

Washing and Liming

The importance of a clean rinse tub is not always appreciated. Ferrous sulphate gradually accumulates in the rinse water, and traces which remain on the steel after rinsing will oxidize upon drying, leaving a film of rust on the surface. Acid also tends to accumulate in the rinse tub and promotes rusting of the steel on exposure to the air.

Complete removal of the last traces of acid with water alone is difficult, even with thorough rinsing in clean tubs. When pickled steel must be protected from rust, an alkaline rinse to remove the last traces of acid is advisable. A hot solution of 0.5% caustic soda and 0.75% trisodium phosphate is effective. The alkalinity of the bath should be checked frequently and maintained by the addition of caustic soda. Acid titration (methyl orange indicator) is the best means of determining the alkalinity; 5 cc. of the above alkaline solution should require 5 to 10 cc. of N/10 sulphuric (or hydrochloric) acid for neutralization.

A cold dip in milk of lime is also effective

for neutralizing traces of acid. This method leaves a coating of lime on the surface which is not easily removed, but in pickling prior to cold drawing operations this is an advantage because the lime acts as a lubricating agent. A white suspension of solid material is not proof that sufficient lime remains in the solution. Calcium sulphate, formed when lime reacts with sulphuric acid, is a white powder which is only slightly soluble in water, and may easily be confused with lime. Titration of the available alkali with a mineral acid gives the correct information.

Pickling Defects

Pickling is frequently blamed for certain defects which appear during the pickling operation but which have their inception elsewhere. The tendency is to blame all failures on over-pickling or to condemn the steel as being defective. Certain troubles, however, are due to neither of these causes, but are the result of earlier operations such as rolling, heat treating, or forging.

Over-pickling is characterized by porosity of the transverse surfaces and a roughening of the whole surface, with discoloration and decrease in size and weight. This can be avoided by removing the material from the bath promptly when pickling is complete. Inhibitors aid in preventing over-pickling, but are not a complete guarantee that it will not occur.

Pickle pitting may be classified into several different types according to cause. As shown in an article by the present authors in *Transactions, A.S.M.* in March, three of these are sufficiently common to justify special consideration.

By far the most prevalent and troublesome type of pitting, particularly on heat treated alloy steels and forgings, is electrolytic. This is characterized by a patchwork of pitted areas of irregular shapes, the depth being indirectly proportional to the area. Such pitting is due to an electrical potential between the scaled areas and clean steel, the pitting occurring only where the scale is removed from small areas prior to pickling or at an early stage in the process. It should be noted that the pitted areas frequently are longitudinally aligned. The boundaries of such pitted areas are usually rather sharply defined or channeled, probably due to maximum potential existing at such locations. However, when inhibited acid is used the pitted area is generally uniform in depth with a channeled boundary; without inhibitors the pits vary in depth.

Although it seldom occurs, severe pitting may be caused by over-pickling, particularly in inhibited acid. This is indicative of carelessness because it appears only when material is allowed to remain in the bath far beyond the time necessary.

Pits which have their origin in the rolling process, due either to rolled-in scale or refractories, are intensified during pickling.

Non-metallic inclusions, segregated carbides, or surface strains are frequently held responsible for pickle pitting. While these factors may have some influence, their importance has been overstressed and it is always advisable first to investigate the causes discussed above.

Blistering is a troublesome defect on sheet and strip steel. Of the several theories advanced

concerning the origin of blisters the most reasonable seems to be that they are due to gaseous inclusions in the steel forming gas pockets just beneath the surface upon rolling. Hydrogen generated in the pickling operation penetrates these pockets and lifts the surface, causing a blister. Properly selected inhibitors may minimize blistering but probably will not entirely prevent it.

Hydrogen embrittlement is a phenomenon that gives some trouble when cold-working operations follow too soon after pickling. It seems to be due to the intermolecular penetration of the steel by nascent hydrogen. This type of embrittlement is not permanent and may be eliminated by aging or more rapidly by soaking the steel in boiling water. Inhibitors are valuable in minimizing this effect.

Interesting Studies of Furnace Refractories of Interest to Metallurgists

A large number of papers were presented before the Refractories Division of the American Ceramic Society at its recent meeting in Columbus dealing with details of making and testing refractories, which were of interest only to manufacturers of such materials. There were, however, a few papers giving results of interest to metallurgists.

A general summary of the uses of refractories in the metallurgical industries was prepared by J. D. Sullivan, of Battelle Memorial Institute. It proved to be so long that only a very brief summary was read. The paper described the refractory requirements in various industries and discussed the performance and life of materials now used. The effect of improvement in refractories on the life of a furnace and on the finished product was also considered. Some of the insulating refractories were considered.

A paper dealing directly with a metallurgical process was given by R. H. H. Pierce, Jr. and J. B. Austin of the Research Laboratory of the United States Steel Corp. They measured the linear thermal expansion of different levels in used silica brick taken from open-hearth roofs to see whether differential expansion could account for the tendency of roof brick to crack and break off. Test samples were cut from bricks taken from an insulated and from an uninsulated roof, in order to compare the expansion under different service conditions. The results show that

there may be two abrupt changes in the character of the thermal expansion along the length of the brick, each of which is large enough to cause serious spalling. The first change comes at that level whose average temperature in service is 2680° F. (1470° C.), and is due to the fact that the silica exists in different modifications on either side of this level. The hotter part consists almost entirely of cristobalite which is the stable form above 2680° F. and which has a large expansion, whereas the adjacent cooler portion is almost entirely tridymite, which has a relatively small expansion. This change in expansion, and therefore a possible zone of weakness, was present in both samples. The second abrupt change comes at the level of furthest penetration of iron oxide and is again due to a sudden change in the forms of silica present. The temperature of this level is believed to be close to 2010° F. (1100° C.), which is the temperature of the ternary eutectic in the system CaO-FeO-SiO₂. As the temperature of the cooler face of the insulated roof was always above this temperature, this zone of weakness did not appear in this brick, indicating that insulation may have advantages in addition to saving heat.

In every case, the differences in thermal expansion are most marked at the cristobalite inversion, which takes place at approximately 480° F. (250° C.); consequently, the greatest danger of spalling or failure (*Continued on page 96*)

Letters and Comment

Difficulties in Determining the "Physical Purity" of Steel

PARIS, France — In the same way that we speak of water containing no insoluble particle visible under the ultramicroscope as being "optically pure," we might also speak of a steel as "physically pure" when it contains no non-metallic particles or inclusions insoluble in the metal that are visible under the ultramicroscope. Admitting that such a condition is practically impossible, it may, however, be taken as a starting point in estimating the degree of physical purity—that is to say, the proportion and the nature of the inclusions contained. This has, in fact, been carried to such a point that in the United States, Sweden and Poland the estimation of inclusions is sometimes specified in the acceptance tests for special steels.

If an analysis evaluates *chemical purity* by determining the percentage of elements considered as detrimental, such as sulphur and phosphorus, it follows that a proximate analysis should determine the *physical purity* by indicating the proportion of the various components of the inclusions such as SiO_2 , Al_2O_3 , FeO and MnO . Such studies on methods of residue analysis have developed much information on the conditions and procedure under which certain reagents dissolve or volatilize the metallic portion without attacking the inclusions (for instance, the halogens, chlorine, bromine, iodine; the acids HCl and HNO_3 ; solutions of metallic salts, iron, copper, and mercury; electrolytic solutions).

Such methods are limited in application, however, by the nature of the steel on the one hand, and the nature of the inclusions on the other. Some steels are immune to attack or con-

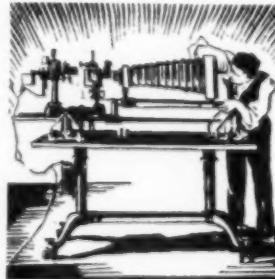
tain structural elements such as complex carbides which contaminate the residue, while inclusions such as basic oxides in particular tend to be dissolved by acid reagents.

Moreover, even when one or more methods can be successfully used to isolate *all* the inclusions in a steel, it may be that they are of several types or extremely complex. The analysis then shows only the ultimate composition of the inclusions in the sample tested, lumped together as a grand average, and not the composition of each of the structural elements. Data obtained from such residue analysis are consequently incomplete and may be compared to data obtained by the chemical analysis of a natural rock containing several mineralogical constituents.

Finally, with the exception of the hydrochloric acid method which is applicable only to a very limited extent, methods of residue analysis are lengthy and delicate, and under no conditions should results be accepted without checking the total oxygen content of the various constituents de-

determined against the total oxygen content as determined by reduction by carbon in a vacuum.

In view of these limitations, it would be impossible at present to introduce such methods of proximate analysis into current practice. Another method proposed is to make a rapid optical evaluation of inclusions under the microscope. Specimens are cut from a position and orientation chosen in accordance with the main outline of ingot or billet; these are supposed to give in-



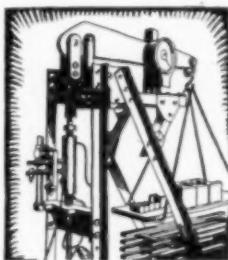
formation on both the nature and proportion of inclusions.

To determine the *nature* of inclusions in this way recourse must be had either to characteristics of chemical attack such as outlined by Campbell, Comstock and Wohrman in the Data Sheet in METAL PROGRESS last November, or to physical characteristics as recommended by Castro and Portevin. The utilization of these methods becomes more and more delicate as the inclusions become smaller, and a purely conventional classification of inclusions into arbitrary categories is the only present alternative.

In estimating the *proportion* of inclusions, it is necessary to take into consideration the number, size computed from the diameter, and density deducted from their supposedly definite nature. This long and laborious procedure is largely influenced by the human element, by the preparation of the surface of the sample and orientation of the fracture on forged steels—Herty and his associates abandoned this method after extensive trials in the United States.

Such results become uncertain and even fantastic when used as a basis for judging the quality of steel. Even supposing that they were correct and independent of the human element for a given sample, the proportion, size and nature of the inclusions will vary from one section to another and even in the same cross section of an ingot. The distribution varies according to the shape and size of the ingot and according to casting conditions; heating for mechanical work, forging and rolling modify greatly the shape of inclusions depending on their nature, the temperature, and degree of deformation.

The size of the inclusions, however, depends on the cooling speed during solidification, since they precipitate progressively in the liquid metal up to the point of total solidification. Thus, a section of a steel casting which has been slowly cooled will contain inclusions clearly visible under ordinary magnification, but a spoon sample from the same heat cast into a small chill mold will show a great number of extremely small inclusions. They are as fine as can be resolved with the ordinary objective; examination under conical illumination at high magnification will reveal a larger number than direct light, and undoubtedly there are many that escape micro-



scopic detection. The steel therefore appears cleaner than it actually is.

All these observations, along with the essentially subjective nature of a procedure which depends so much upon the human factor, lead to the conclusion that this method of determining physical purity should be limited to the control of operations in one plant, always executed by the same operators, and that the introduction of such methods into specifications as a criterion of steel quality is not yet feasible.

ALBERT PORTEVIN

Upper and Lower Yield Point

WARSAW, Poland—In the translation and abridgment of my letter published in March METAL PROGRESS under the caption "Does Upper and Lower Yield Point Have Actual Existence?" some misinterpretations have appeared, especially in the summary contained in the next-to-last paragraph. This paragraph may be more properly amplified as follows:

"It is fairly evident that the tension-elongation diagrams recorded by the customary tensile test machines do not in most cases represent the real properties of soft materials. More especially the yield point calls for correction. There is no upper or lower yield limit for mild steels; the upper yield point, so-called, is contingent on the design of the testing machine, and is therefore an imaginary idea. As a matter of fact, even with a rapidly increasing elongation the stress beyond the yield limit will increase steadily.

"Furthermore, it has been ascertained that the maximum load limit must tally with the breaking strength of the test pieces, and that here again no drop in load is to be recorded.

"The effective resistance values of all materials with a contraction as calculated from the usual tensile diagram call for some rectification in so far as they are higher throughout than the actual effective tensile resistance values of these materials as determined. These values are thus brought somewhat closer to the theoretically calculated absolute tensile resistance values. Apart from this, the so-called integral degree of the materials calculated from the total area of the tensile diagram is changed materially, and this more particularly with hot tensile tests, where frequently a severe drop of load is observed prior to breaking, due to marked contraction."

G. WELTER

Institutes for Research Into Ferrous and Non-Ferrous Metals

SCHWEINFURT, Germany — Three recent events in Germany should be of interest to American metallurgists: The opening of the new Kaiser Wilhelm Institute for Research in Metals, June 21, 1935, in Stuttgart; the opening of the new Kaiser Wilhelm Institute for Ferrous Research, Nov. 29, 1935, in Düsseldorf; and the 25th anniversary of the founding of the general organization known as the Kaiser Wilhelm Association for the Advancement of Science.

Kaiser Wilhelm Association for the Advancement of Science was founded Jan. 11, 1911, in Berlin under the protectorate of the German Kaiser and Prussian King to enable a select group of scientists to devote themselves to scientific research without other distractions. It was thought that the professors at the universities and technical high schools, to say nothing of outlying institutions of higher learning, burdened with the double duty of teaching and research, could not do justice to problems of any magnitude. At the beginning the existing resources were especially devoted to the natural sciences, since this field required special facilities, apparatus, and laboratories. In a short time a capital of about 15 million marks was provided and additional income of over 100,000 marks guaranteed from annual membership dues.

From this endowment 30 institutes have since been formed, which can be segregated into three groups: (a) The chemical, physical, and technological institutes, 13 in number; (b) the biological, anthropological, and zoological institutes, 13 in number; (c) the institutes for intellectual science or humanities, four in number.

The importance and accomplishments of these institutes cannot even be briefly outlined in the space at my disposal. A well illustrated and authoritative handbook has been issued by the Association, edited by the first president, which should be consulted. It is published by Reimar Hobbing, Berlin, S.W. 61.

The first president of the Kaiser Wilhelm Association was Adolf von Harnack, who died in 1929. Harnack House in Berlin-Dahlem, now headquarters for German scientists and foreign visitors, was named in honor of his memory. Successor to von Harnack was the well-known physicist and Nobel prizeman, Max Planck, under whose leadership the 25th anniversary was celebrated on Jan. 1, 1936.

In his speech he told how sincerely indebted is the Association to the government for its active support. A recent instance might be the founding of the Kaiser Wilhelm Institute for Physics in Berlin-Dahlem, whose building and equipment were provided by a large bequest from the Rockefeller Foundation, and whose operation is guaranteed by appropriations from the national ministries of science and education. Director of the Kaiser Wilhelm Institute for Physics is Dr. P. Debye, internationally known savant.

Metallurgists would naturally be most interested in those two institutes devoted to research into iron, steel and non-ferrous alloys. On Jan. 1, 1920, was organized the K.W.I. for Research in Non-Ferrous Metals in Berlin-Neubabelsberg; the late E. Heyn was the first director. In 1923 the Institute was housed with the Governmental Department for Testing Materials in Berlin-Dahlem and Oswald Bauer appointed acting director. Reports on the work carried through since that time have appeared mostly in *Zeitschrift für Metallkunde*.

After 14 years of activity in Berlin the Kaiser Wilhelm Institute for Research in Non-Ferrous Metals was moved to Stuttgart, and there combined with two local organizations already established, the Stuttgart Institute for Physical Chemistry and for Röntgenology, all three forming the enlarged Kaiser Wilhelm Institute for Research in Metals under the direction of Werner Köster. This move resulted from the realization that the rapid and significant developments in the field of metallurgy warranted the establishment of a chair of applied metallurgy at the Stuttgart Technical College. The necessary means were thereupon provided by the province of Württemberg, the city of Stuttgart and most especially by the industries interested in copper, zinc, lead, aluminum and their alloys.

This "little brother," as Dr. Köster termed it recently, supplements the "elder brother," the Kaiser Wilhelm Institute for Ferrous Research in Düsseldorf. This was founded June 6, 1917, by a resolution of the German Iron and Steel Institute (Verein deutscher Eisenhüttenleute, V.d.E. in short). Hence it follows that the Kaiser Wilhelm Institute for Ferrous Research is supported



by an assessment of German iron and steel industry, based on production. The first director was Dr. F. Wüst of Aachen, who was succeeded in 1922 by Friedrich Körber. The research work was modeled on the plan still in use at the Institute for Ferrous Metallurgy in Aachen, developed under the guidance of Dr. Wüst.

Due to the exigencies of War-time, no new construction was attempted in Düsseldorf, but a

large workshop was repaired and opened on Nov. 26, 1921. In spite of the important work accomplished in this structure, there was always a desire to possess a new and more appropriate home, better adapted to the needs of the times.

In order to fulfill this wish, the necessary actions were taken by the V.d.E. and the cornerstone laid on June 3, 1934, during its annual convention. The new laboratory was formally opened on Nov. 28, 1935, by Max Planck, president of the Kaiser Wilhelm Association for the Advancement of Science. One must visit this modern building to appreciate its many advantages.

A review of the many fundamental problems studied by the institute (such as those published in *Mitteilungen des Kaiser Wilhelm Institut für Eisenforschung, Stahl und Eisen*, and *Archiv für das Eisenhüttenwesen*) will show how important this research group has been and will be in the future, not only for Germany but for the whole civilized world. This was emphasized by M. Tigerschiöld of Stockholm in his congratulatory speech at the last metallurgical meeting as spokesman for the foreign guests.

Future prospects can be forecast by a retrospective view of the past, corroborated by the success of the German Iron and Steel Institute (V.d.E.), which celebrated its 75th anniversary on the day the new building of the Kaiser Wilhelm Institute for Ferrous Research was dedicated. What has been accomplished by the V.d.E. in these 75 years has been described in a comprehensive history by Dr. O. Petersen, summarized in extenso in *Stahl und Eisen*, 1935, p. 1253 to 1440.

Relying on tradition, German metallurgists are looking hopefully to the future with the new institutes in Düsseldorf and Stuttgart.

HANS DIERGARTEN



Impact Test Piece With 2-Mm. Notch Best for Alloy Steel

TURIN, Italy — In the ordinary commercial static tests of metals, the effects of varying testing conditions on the results of such tests are fairly well known, so that the results of different series of tests (particularly of tensile and hardness tests) can be compared, even when made by equipment of different design and manufacture. On the other hand, the data available at present concerning the determination of the impact resistance of metals are not sufficient to allow us to compare the results of a given test with those of others made under different conditions. It is well known that this is one of the major obstacles to the general introduction of the impact test in commercial laboratories.

Since the fundamental importance of the impact test for the complete knowledge of the technical quality of the metal is admitted, every attempt to overcome the uncertainties in such a test has the greatest practical importance. One means for eliminating the above-mentioned obstacle would obviously be the fixing of standard conditions for impact testing.

The problem of determining and adopting such standard conditions has formed the object of many important discussions, both in the technical press and in congresses and conventions. Their general conclusion, however, has been that the data available at present are inadequate, and a great number of further exact experimental results are necessary before any definite statement can be made of the best conditions to be adopted for commercial standards.

In one of my preceding letters (January, 1935) I quoted the results of a group of interesting experiments made by A. Steccanella of the Italian State Railways, with the object of answering some questions about impact tests on plain carbon steels, as rolled and without special heat treatment. As a result of some 100,000 tests, Steccanella found that the standard Mesnager bar (10x10x55 mm., notched 2 mm. deep with bottom rounded to 1 mm. radius) was better than other types investigated in the giving of uniform results on carbon steels known to be uniform, and sharply differentiating between materials known to have different quality, composition and history.



The same author has now extended his experiments to other types of steels, including nickel and nickel-chromium steels, rolled and heat treated under well-defined conditions. Results of a very great number of tests seem to show a few facts that should be taken into account in the study of standard conditions for the commercial impact test:

On the form and the dimensions of the notched bars a certain agreement has been reached in the last International Congress for Testing Materials, so that the 10x10x55-mm. test bar with a rounded notch 2 mm. wide may be considered the international or at least the European standard.

The only point on which a general agreement has not been reached hitherto is the depth of the notch. The depths more generally adopted in Europe are 2 mm. in the Italian standard specifications, 3 mm. in the German standard specifications, and 5 mm. in the French standard specifications.

In regard to this different practice the following light has been shed by Dr. Steccanella's new experiments:

1. The 2 and 5-mm. notches are practically equivalent, and both much superior to the 3-mm. notch as to the uniformity of results of duplicate tests on the same material.

2. The 2-mm. notch is better than the 3 and 5-mm. notches in showing differences of impact resistance of a given material, reheated under different conditions during manufacture.

3. The 2 and 3-mm. notches show more clearly and much more regularly than the 5-mm. notch the different impact resistances of a given material, heat treated under different time and temperature cycles.

These facts seem to lead to the conclusion that the 2-mm. notch should be recommended for the standard test bar.

Another result of these extensive experiments is to show the undesirability of using a V-shaped notch, since the test results obtained with it are irregular, except for very low carbon steels. In addition to that, the results obtained with the V-notch, even for very mild steels, are no better and no more uniform than those obtained with the other notches, so that the use of this extra test bar seems unnecessary, if not in fact undesirable.

As a conclusion of his researches, Dr. Steccanella tries to establish some rules for computing the value of impact resistance for a given notch from the results of actual tests made with

another type of notch. Although the average figures established by him are based on a very large number of experiments, the results obtained are not yet constant enough to be taken as a basis for practice. However, they seem to show the possibility of reaching this desired end when more complete experimental data become available for statistical analysis.

FEDERICO GIOLITTI

Multiple Tempering of High Speed

GROSNY, U.S.S.R.—Since the chief advantage of high speed steel in comparison to carbon tool steel is red hardness and secondary hardness obtained by tempering the hardened tools at suitable temperature, great efforts should be taken to insure the maximum of these unique properties.

According to the recommended practice for the heat treatment of 18% tungsten high speed steel in A.S.M. Metals Handbook, 1930 edition, tempering for secondary hardness should be done by reheating the steel uniformly to 1050 to 1150° F. for a sufficient length of time, and then cooling in air. In practice the time at tempering temperature is about 1.5 to 2 hr.

The phenomenon of secondary hardness of high speed steel is ascribed to the transformation of austenite (retained in steel after quenching) into martensite, and by the precipitation of carbides from solid solution in a very dispersed condition. While it may be difficult to separate the effects of these two reactions, it is generally believed that the transformation of austenite takes place during the reheating of steel for tempering as well as during the time it is held at temperature.

It is doubtless the opinion of most metallurgists that the above recommended method of tempering high speed steel is suitable for obtaining a sufficiently complete change of austenite into martensite, and for the best combination of secondary hardness and high cutting properties of the tools. However, A. Michel and P. Benazet, when investigating some high speed steels containing 10 to 20% cobalt, found that single tempering does not fully transform the austenite, since the action continues during subsequent temperings with a simultaneous increase in the secondary hardness. Their findings, published in *Revue de Métallurgie* in 1932, indicate that austenite transforms into martensite at temperature below 600° F. during the cooling after tempering. Furthermore, (Continued on page 74)